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1 OF 2
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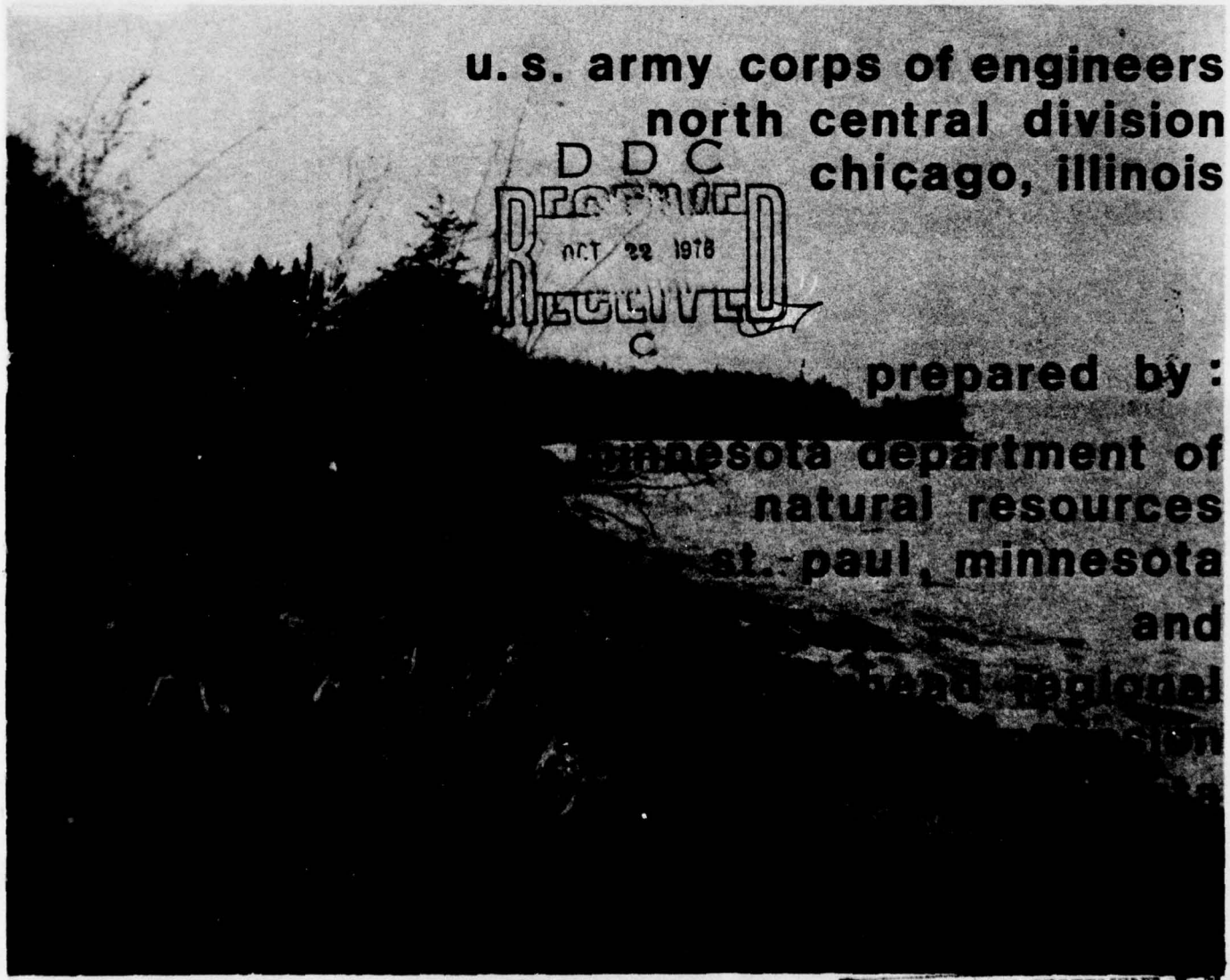
great lakes shoreline damage survey

saint louis county, minnesota



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This is an appendix to the Summary Report of the Pilot Study Program, Great Lakes Shoreland Damage Study. It is a study of St. Louis County, Minnesota, shoreland damages caused by, or directly related to, the 1972-1974 high water period on the Great Lakes. Aerial photo mosaics of county shorelands are also included.

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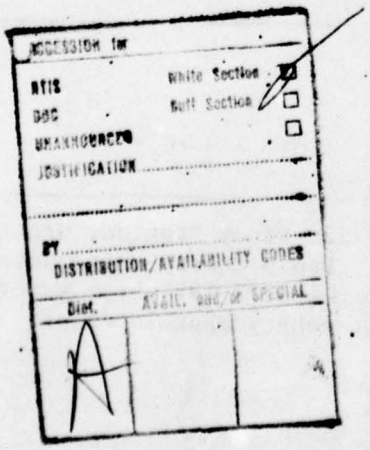
Main Report	**Summary Report of the Pilot Study Program, Great Lakes Shoreland Damage Study.**
Appendix I	**Great Lakes Shoreline Damage Survey; St. Louis County, Minnesota**
Appendix II	**Great Lakes Shoreline Damage Survey; Brown, Douglas, and Racine Counties, Wisconsin.**
Appendix III	**Great Lakes Shoreline Damage Survey; Muskegon, Manistee, Schoolcraft, Chippewa, Alcona, and Huron Counties, Michigan**
Appendix IV	**Contract for a Damage Survey of Oswego County, New York**
Appendix V	**Shoreline Damage Survey: An Appraisal with Recommendations**
Appendix VI	**Engineering - Economic Analysis of Shore Protection Systems: A Benefit/Cost Model**
Appendix VII	**Measurement of Coastal Bluff Recession from Aerial Photographs, Muskegon County, Michigan**
Appendix VIII	**Comparison of Field Data Collection to Date Collected Using Study Instruments in Muskegon and Manistee Counties, Michigan**



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1.0 INTRODUCTION

1.1 AUTHORITY AND SCOPE

This shore damage study of St. Louis County, Minnesota, was conducted under authority of Contract No. DACW 23-75-0023 by the State of Minnesota for the Corps of Engineers. The contractor, being the State of Minnesota, further subcontracted with the Arrowhead Regional Development Commission in Duluth, Minnesota to perform the required work and services. The study is accomplished under the survey scope authority for the Great Lakes Water Level Study.

The activities required as part of the contract include development and management of a self-administered shoreland damage assessment program, follow-up field interview, on-site inspections and field surveys, office computations and analysis, and report preparation.

The following tasks were to be accomplished under the study:

1. Compile a list and prepare maps of shoreline ownership, use, and description in St. Louis County.

2. (a) Print and distribute a self-administered Great Lakes Shoreland damage assessment to all known residential shoreland owners.
(b) Analyze and compile the results of the returned assessments.

3. Conduct a follow-up personal interview of a random sample of residential property owners to further support and evaluate the information provided by the mail response.

4. Conduct a field damage survey of commercial/industrial, public buildings, transportation facilities, and public and private utilities.

5. (a) Compile a list of existing erosion and flood protection structures.
(b) Provide general evaluation of their effectiveness, including damage reduction benefits, costs, and physical condition.

6. Prepare maps showing the estimated extent of areas inundated by flood waters.

7. Conduct damage surveys of flood plain areas by interviewing flood victims.

8. (a) Collect information on the shore damages, including newspaper accounts of storm damages and available photographs of damaged areas.
(b) Present this information in appendices to the report.

9. (a) Summarize the shoreline recession rate based on information supplied by the individual property owners.
(b) Compute the volumetric contribution of bluff erosion to the Great Lakes sedimentation based on this data, and provide bluff and surf zone profiles.

10. Compile available information on the effects of high water on recreational opportunities and aesthetic and environmental values.

11. Prepare maps, charts, and graphs to illustrate the results of the damage survey.

12. Prepare a draft and final report with appendices.

1.2 BACKGROUND INFORMATION

This is a pilot study of St. Louis County shoreland damage caused by or directly related to the 1972-1974 high water period on the Great Lakes. The study is a cooperative undertaking of the State of Minnesota and the Corps of Engineers to develop reliable estimated shore damage data. The compiled information will be shared with other Federal and State agencies. This information will provide a base of information needed for the implementation of many Federal and State Programs directed at reducing shoreland damages.

The Corps of Engineers initiated the evaluation of the Great Lakes Shoreline flooding and erosion damage situation with a data gathering study in 1952. A preliminary report was completed in June of 1952. It discussed Great Lakes shoreline damages for the period May 1951 to April 7, 1952. The International Joint Commission (IJC) began its lake level study in 1965, and completed it in 1973. The return of high water levels on all of the Great Lakes in 1972-1974 coincided with the completion of the lake levels report. The resulting report recommended several alternative plans for regulating Great Lakes levels in order to maximize benefits to lake users and minimize adverse effects of regulation. One of the conclusions of the study indicated that additional net benefits could be achieved by modifying the existing regulation plan. It was implemented as an emergency action under instructions from the IJC in 1973.

SO-901 was designed to balance the water levels between Lake Superior and Lakes Michigan-Huron. When Superior is high relative to Michigan-Huron, more water would be released. When Michigan-Huron levels are high realtive to Superior, less water would be released from Lake Superior. Under the SO-901 plan, it was acknowledge that benefits would accrue to shipping interests, hydro-power production and shoreline property interests on the lower lakes. On Lake Superior benefits would accrue to shipping, while losses would be experienced by Lake Superior hydroelectric power and riparian interests. The benefit/cost analysis of SO-901 was derived from basic data gathered in 1951-1952. This data base was considered to be in need of updating. Accordingly, 11 county pilot studies were initiated around the Great Lakes to study damages. This study is one of the 11 pilot studies.

1.3 ACKNOWLEDGEMENTS

The report itself is a compilation and analysis of data collected by the Arrowhead Regional Development Commission (ARDC), with the aid of several other contributing individuals and agencies. Several sections

were written by the Minnesota Department of Natural Resources.

The Arrowhead Regional Development Commission was officially created under the Regional Development Act of 1969. It was authorized to receive planning grants and was required to prepare a regional development plan. The Commission is also required to review comprehensive plans of local government and independent agencies, and local government applications for Federal and State aid programs. The Commission may also contract to obtain or perform services with state agencies, non-profit regional groups, etc.

The State of Minnesota contracted with the Arrowhead Regional Development Commission to perform certain services as specified in the Authority and Scope of this report.

The other individuals and agencies who contributed information to the survey are listed below.

Corps of Engineers (Duluth Area Office of St. Paul District)

Soil Conservation Service

Minnesota Department of Natural Resources

St. Louis County Board of Commissioners

St. Louis County Assessor

St. Louis County Auditor

St. Louis County Highway Department

City of Duluth Parks and Recreation

City of Duluth Engineer's Office

City of Duluth Assessor's Office

Dr. John Green, University of Minnesota-Duluth, Geology Professor

Geology Student Interns from the University of Minnesota-Duluth

Joel Ahlquist	Bruce Woodhouse
Craig Anderson	Jay Brunner
Earl Fashbaugh	Mike Johns
David Hoag	Mike Madden

2.0 SHORELAND DESCRIPTION

2.1 GENERAL

The St. Louis County Study Area fronts Lake Superior for 69.8 miles (111.7 km). Lake Superior is the world's largest fresh body of water having a surface area of 31,820 square miles. Lake Superior is also the deepest of the Great Lakes with a maximum depth of 1,302 feet. The St. Louis County segment of Minnesota's North Shore (total length of approximately 163 miles or 261 km.) comprises the western most one-third of the littoral zone extending from the St. Louis River, adjacent to the U.S. Steel Industrial Site at Gary-New Duluth, northeastward to the St. Louis County/Lake County Line. It was administratively determined that the Spirit Lake portion of the St. Louis River estuary represented the uppermost reaches where rising levels in Lake Superior would have an impact. Minor Civil Divisions located within the study area are the City of Duluth and the Townships of Duluth and Lakewood.

The primary purpose of this survey is to inventory the direct and indirect economic effects of near record high water levels on Lake Superior. Existing shoreforms and property have become increasingly vulnerable as the lake level has risen above the long term low water datum of 600 feet to greater than 602 feet. Impacted areas treated by this investigation extend from the south ½ of Section 36, T 49N, R 15W, West Duluth quadrangle to the NE ¼ of Section 36, T 52N, R 12W (Knife River USGS quadrangle). The St. Louis County shoreline (extending northeast-southwest from 46 degrees 40 minutes North Latitude to 47 degrees North Latitude and centering on 92 degrees West Longitude) has been divided into four reaches, three of which possess distinct natural qualities and limited riparian development. The remaining sector lies within the Duluth Harbor area and represents extensive shoreland modification. It also contains most of the areas's protective devices to be discussed later.

Duluth and the remaining St. Louis County study area are characterized by cool annual mean temperatures (average mean annual temperature 40 degrees F.), sufficient precipitation in all months (average annual mean 28 inches), and considerable variability in temperatures from day to day. The prevailing wind pattern is from the northeast. Regions immediately adjacent to Lake Superior undergo significant temperature modification; however, there is little evidence that the presence of the lake increases annual precipitation. Average dates of the last and first killing frost are May 13th and October 3rd, respectively.

Duluth's location near the geographic center of North America accounts for its continental climatic condition; yet the existence of the lake and nearby landforms influences local temperatures markedly. Orographic lifting and/or the subsidence of air masses near the lake causes Duluth and the North Shore to be shrouded in fog an average of over 50 days per year. Despite high relative humidity throughout the warmer seasons, area residents experience less discomfort than might be expected because few days attain temperatures greater than 80 degrees.

The geology of the St. Louis County study area can be briefly described by the major geologic formations. The St. Louis County shoreline is underlain exclusively by pre-Cambrian rock covered by glacial deposits from succeeding ice invasions. The younger rock formations found in the study area are basaltic and felsic lava flows and associated intrusive rocks. The lava flows are from the Keweenawan age and extend up to 20 miles inland. These lava flows are intruded by dikes and sills of diabase which form much of the relief along the study area. At one time the entire study area was engulfed by Glacial Lake Duluth. Remains of this last glacial activity include the skyline bluffs of Duluth and the heavy red clay deposits and old beaches scattered along Lake Superior's shoreline.

2.2 PHYSICAL DESCRIPTION OF THE REACHES

The St. Louis County Study Area includes four areas (Reaches) selected because they represent coastal sections of distinct origin and landform continuity (See Plate 1). Reach 1 extends 7.5 miles (9.9 Km) from the former docking facility adjacent to the U.S. Steel Plant in Gary, to 63rd Avenue West. Reach 2 stretches 25.9 miles (41.44 Km) from 63rd Avenue West to Lake Avenue. Minnesota Point constitutes Reach 3 (17.15 miles or 27.44 Km), while the remainder of the St. Louis County shoreline from Lake Avenue to the St. Louis/Lake County line (19.2 miles or 30.72 Km) comprises Reach 4. A physical description of each of the four reach areas will follow.

REACH 1

Reach 1 is largely non-residential or undeveloped and comprises the north bank of the St. Louis River estuary. The depositional clay silt banks are underlain with bedrock formations composed of dipping Keweenawan intrusives and Puckwunge sandstone. Approximately 55 percent of the bank material is a clay and silt intermixture, the remainder being sand and rock. Referring to Plate 2, four basic shoreform types comprise Reach 1: wetlands, artificial fill areas, erodible low plains and low bluff erodible areas. The low plain and low bluff erodible areas dominate the shoreline topography with limited wetlands and a confined artificial fill area found south of Tallas Island in Riverside. Vegetation presently providing cover on these low slopes includes various low-grade softwood conifers and small hardwood deciduous species such as ash, popple, white birch and elm. Reach 1 provides the only significant wildlife habitat along the entire riparian expanse of the study area. The vegetative cover and minimal slope tend to diminish the threat of severe surficial-runoff conditions which contributes to erosion processes of some of the other study area reaches.

Reach 1 has a very moderate wave climate and is primarily susceptible to flooding conditions. The naturally embayed area appears to be affected by both the St. Louis River and the rising water levels of Lake Superior.

REACH 2

Reach 2 is of greater length than Reach 1 and is developed and urban in character. The 25.[illegible] miles of Reach 2, was at one time physically very similar in appearance to Reach 1, but has since been modified with respect to shoreforms, vegetation and the waterway itself. Reach 2 can be labled as a low-bluff depositional clay silt bank of the St. Louis River Estuary. The reach has the same geologic formations as that of Reach 1. Physically, the only difference between Reaches 1 and 2 is the level of development and the sizeable artificial fill areas which have altered the shoreline and provided desired harbor industrial and commercial sites. Being a deep-draft navigational harbor, Duluth shipways and channels are maintained to a depth of 27 feet. An expanse of almost completely artificial shoreline extends from Hallet Dock #5 to the Duluth Ship Canal. Sluices, landfill areas, extensive dock and breakwater construction account for this artificial shoreline (see Plates 2-6).

The artificial fill areas have been created over the years from dredge material supplied through channel maintenance and periodic harbor development. The degree of slope along Reach 2 is very minimal; however, overall soil permeability and drainage is good along this littoral zone. Shoreline profiles along the Reach 1/Reach 2 continuum show bluff height ranging from 3 to 28 feet. Vegetation in the Reach 2 area is practically non-existent except for along Grassy Point.

The embayed harbor (Reach 2) is naturally protected by the Minnesota Point sand spit and is subject to a moderate wave climate. The relatively low lying nature of the area and development pressures on the immediate waterfront have made the Reach 2 area very susceptible to both flooding and erosion problems.

REACH 3

Reach 3 is composed of Minnesota Point, a 600 acre sand spit formed naturally between the North and South shores of Lake Superior. (Refer to Plates 6-10) Minnesota Point varies in width from about 300 feet to 1,400 feet, and has a shoreline stretching for approximately 17.2 miles. Geologic development of this natural sand bar is theorized to be a result of three factors. 1) receding glacial lake activity, 2) sedimentation from the St. Louis and Nemadji Rivers, and 3) wave action and its effect on the natural littoral drift of materials. Soil composition along Reach 3 is about 85 to 89 percent quartz sand over clay or clayey till. The remaining soil material is a silt-clay sediment from harbor dredging which has contributed to shoreline development in the form of artificial fill.

It has been pointed out that natural forces have built Minnesota Point; however, man has contributed several alterations which influence the natural drift of materials along the lakeward Reach 3 shoreline.

Two major engineering structures have been built along the spit. The Duluth Ship Canal was dug through Minnesota Point in 1871 and consists of two concrete piers, 2000 feet long and 300 feet apart. The second structure is the concrete Superior Entry breakwaters built in 1869 and extending 2,000 feet outward into Lake Superior. (Refer to Plates 6 and 9) A study has recently been completed by the Corps of Engineers, St. Paul District,[1] to determine what effects the two groin structures (Duluth Ship Canal and the Superior Entry) have had on the natural beach nourishment process afforded by the longshore littoral drift of materials. The purpose of the study was to evaluate the need for a long-range beach nourishment program in this area.

Minnesota Point serves as a natural protective harbor barrier and also proves to be environmentally sensitive. The shoreforms along Reach 3 consist of artificial fill areas and low sand dunes less than 30 feet in elevation (See Plates 6 through 10). The harbor side has been modified over the years with deposits of dredge material. The filled areas have vegetation in the form of grasses, shrubs and sparse tree growth, but generally remains relatively low. Along the lakeward side of Minnesota Point, between the two harbor entrances, lies a long flat sand beach and sand dunes. Dune formations range in elevation from 10 to 25 feet and are found in the backshore areas along the entire lakeward shore beginning about 3,000 feet southeast of the Duluth Ship Canal. The dunes are considered to be very fragile and are of environmental concern.

The lakeward beach is characterized by a 5 to 7 degree slope. Lateral gradation of the beach sediments by mean particle size is evident on the point. The greatest quantity of beach material falls within the class of medium to coarsely-medium in particle size (2.0 to .5 Wentworth size classification). The principle mechanism in the sorting of beach materials are translittoral waves associated with small swells produced by normal weather and current circulation. Oscillatory waves result from major storms on Lake Superior and constitute the principle erosive threat to this unprotected shoreline.

Reach 3 is subject to two distinct wave climates. The harbor or embayed side of Minnesota Point is protected from severe wave attack and has a very moderate wave climate comparable to Reaches one and two. The lakeward segment of the Reach 3 shoreline is subject to severe wind driven wave attack, particularly northeasterly, in which the waves are coming down the maximum fetch of Lake Superior and pound the open-coastal shore. The fetch from the northeast is approximately 200-500 miles.

The geomorphic character of Minnesota Point makes it susceptible to both flooding and erosion. The embayed side of Reach 3 has a low lying relief and is subject to flooding and erosion conditions. Development along the embayed shoreline is relatively close to the waters edge

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[1] Section 111 Detailed Project Report - Beach Erosion Control on Minnesota Point at Duluth, Minnesota, U.S. Army Engineer District St. Paul, Corps of Engineers, St. Paul, Minnesota, November 1974.

whereas on the lakeward side development is up and beyond the dune formations, therefore limiting flooding. Erosion is the predominant damage condition experienced along the open coastal Reach 3 shoreline.

REACH 4

The 19.2 miles of Reach 4 shoreline is the result of the process of volcanism in which a bedrock escarpment extends from the depths of Lake Superior to the approximate elevation of the Duluth skyline. The face of the escarpment is of the Duluth/Gabbro complex composed of Keweenawan intrusives interposed by diabase sills and veneered with pebbly red clay till. About 85 percent of the igneous Keweenawan formations are basic extrusives of melaphyre and ophite, about 5 percent are acid rhyolites and felsites; the remaining 10 percent are Oratrase sills or dikes. Small coves, spurs and pebbly beaches form the anterior coastal sections. Where rock outcroppings do not exist along the shore, the bluffs are protected by bouldery beaches. The unconsolidated red clay bluffs are located primarily on the northern part of Reach 4 northeast of Lester River. Massive slumping and mass wasting of the unconsolidated materials is causing the undermining of trees and brush along the lakeward bluff perimeter. A contributing factor to the weakening and slumping of the clay bluff is surficial run-off and ground water seepage. (See Appendix B and Plates 11-19).

Shoreforms along Reach 4 are categorized as low bluff erodible (less than 30 feet in elevation), low bluff non-erodible (less than 30 feet in elevation), and high bluff erodible (greater than 30 feet in elevation). Refer to Plates 10 through 19 for a graphic analysis of shoreform conditions.

Vegetation presently providing cover on these various slope elevations includes low grade softwood conifers and small hardwood deciduous species such as ash, popple, white birch and elm. Grasses and brush are also present along the tops of the bluffs and clay banks.

Reach 4 being an open-coastal area is subject to a very intense wave climate. Deep water oscillatory waves during northeasterly wind conditions are known to mount an extreme wave attack pounding the entire Reach 4 expanse. The storm produced wave actions have the capability of destroying vulnerable bluff toe areas thereby enhancing other hydraulic erosion processes and magnifying the entire problem.

2.3 LAND USE, OWNERSHIP AND VALUE

Land Use

The St. Louis County Study Area is composed of a variety of land use types common to an urbanized shoreline area. For the purposes of this study, land uses are categorized as follows: residential, commercial/industrial, manufacturing, utilities, and tax-exempt. A total of 878

individual parcels were identified in the study area. Of this total, 345 are residential and the remaining 533 are non-residential.

TABLE 1

Breakdown of the study area parcels by Reach:

Reach 1 =	39	4 residential 35 non-residential
Reach 2 =	212	5 residential 207 non-residential
Reach 3 =	300	123 residential 177 non-residential
Reach 4 =	327	213 residential 114 non-residential
	878	Total Parcels

Reviewing Table 1, it evident that residential land use is largely concentrated in Reach 3 and 4, with non-residential development dominating Reach 1 and 2. Each of the four reaches will now be examined in terms of specific land uses and their location. Reference should be made to Plates 2 through 19 and Tables 6A and 6B for an analysis of land use, ownership and value conditions in the study area.

Reach 1 is largely tax-exempt (29 parcels) with some manufacturing at Morgan Park (2 parcels), commercial development at Riverside (3 parcels), industrial use along the Reach 1/Reach 2 boundary (1 parcel) and residential land use south of Indian Point (4 parcels). Heavy manufacturing and industrial land usage once existed in Reach 1. Such activity has diminished over the years, and most of this land is in an abandoned state at this time. Reach 1 can be characterized as a low density/ undeveloped shoreline.

In recent years, the Reach 2 harbor area has experienced the majority of new non-residential development and is considered highly developed in terms of density and diversity of land use. Reach 2 is comprised primarily of manufacturing and heavy and light industrial uses. These two land use types occupy 114 of 212 total parcels in Reach 2. Of lesser frontage are tax-exempt land (89 parcels), a major utility (2 parcels) and minimal residential development (5 parcels). Generally speaking, land uses are scattered throughout Reach 2 with residential development concentrated in the vicinity of 63rd Avenue West. References should be made to Plates 2 through 6 for a delineation of uses and their locations.

Development along both shores of Minnesota Point (Reach 3) is dominated by residential and tax-exempt parcels (123 and 98 parcels respectively), with limited commercial (1 parcel), industrial (46 parcels), manufacturing (18 parcels) and utility uses (6 parcels). Various government levels hold

title to land scattered along the Point, most of which are sparsely developed. Residences are found along both sides of Reach 3 beginning southeast of the Duluth ship canal and extending to the Park Point Recreation Area. Non-residential development is concentrated northwest of the Duluth ship canal along both the harbor and lakeward shores. Other non-residential development is situated southeast of the Duluth ship canal (Harbor Shoreline) and at the end of Minnesota Point near the Superior entry. Refer to Plates 6 through 10 for a graphic analysis of land use conditions in Reach 3.

As was the case in Reach 3, land use along Reach 4 is predominantly residential and tax-exempt lands (213 and 61 parcels respectively). Some of Duluth's finest homes are found along the bluffs of Reach 4. Non-residential development is limited to commercial and industrial land uses which are located intermittently along the entire reach. The intensity of development in Reach 4 varies due to the limited availability of land. Sizeable tax-exempt parcel holdings act as buffers between development concentrations thereby varying the intensity of development conditions. A prime example is the Congdon Parkway or Boulevard extending from Lester River several miles beyond the Duluth corporate limits. Development along this section of shoreline is limited because of the ownership conditions and availability of land for development. In essence, Reach 4 is largely residential, superimposed by parks and other open space tax-exempt parcels. (See Plates 10 through 19 for a better understanding of land use activity in Reach 4).

Ownership

Lands along the St. Louis County littoral zone are primarily in private ownership with remaining parcels belonging to various government levels including Federal, State, County, and Municipal units. Of the 878 total study area parcels, 15 are federally owned, 96 belong to the State of Minnesota, 2 are held by St. Louis County, 121 are in City of Duluth title, 13 are unclassified by the assessors records (parcels were in title transition), and the remaining 631 are in private ownership.

TABLE 2

Breakdown of Parcel Ownership by Reach:

Reach 1 (39 parcels)	
State of Minnesota	7
City of Duluth	22
Private Sector	10

Reach 2 (212 parcels)	
State of Minnesota	40
City of Duluth	22
Private Sector	147
Unclassified	3

Reach 3 (300 parcels)	
U.S.A	15
State of Minnesota	37
St. Louis County	2
City of Duluth	39
Private Sector	197
Unclassified	10

Reach 4 (327 parcels)	
State of Minnesota	12
City of Duluth	38
Private Sector	277

The State of Minnesota and the City of Duluth are the two major government entities holding title to public lands in the St. Louis County Study Area. Table 2 reveals that reach ownership is dominated by the private sector except in Reach 1 where the opposite situation is true. An average of 73 percent of the parcels in Reach 2,3, and 4 are privately owned. It should be noted that Reach 3 shows the greatest diversity in land ownership, unlike the other three reaches which exemplify similar ownership patterns. Refer to Plates 2 through 19 for a graphic analysis of ownership conditions.

Property Value

Property values for each parcel in the St. Louis County Study Area was obtained from the City of Duluth and St. Louis County tax rolls. Property values were found to be variable throughout the study area depending upon the land use type and location. Average property value is presented both by front footage and per parcel in Table 3.

TABLE 3

Average Value of Riparian Properties in the St. Louis County Study Area

1. Average Value/Parcel

Reach 1	$ 6,700	Reach 3	$12,700
Reach 2	68,300	Reach 4	6,000

2. Average Value/Foot Frontage

Reach 1	$ 7.00/ft.	Reach 3	$42.00/ft.
Reach 2	106.00/ft.	Reach 4	19.00/ft.

2.4 SHORE PROTECTION (ST. LOUIS COUNTY)

Shore protective actions have been undertaken in the St. Louis County Study Area to combat flooding and erosion conditions. Information on shore protection activity was obtained from the mail out questionnaire, personal interviews and field reconnaissance. Refer to Table 7, Plates 2 through 19, and Appendix A for supplementary information and photographs on the types, location and effectiveness of shore protection measures.

The St. Louis County shoreline is subject to two distinct types of wave exposure as outlined in the previous discussion of physical reach characteristics (Section 2.2). The first shoreline type includes the open coast, high wave exposure climate found in Reach 4 and the lakeward side of Reach 3. The second type, includes the embayed, moderate wave conditions found in Reaches 1 and 2 and the bayside of Reach 3.

Protective structures observed in the open coastal areas range from superficial rip-rap to more permanent stone revetments and groins. Due to the severity of wave climates found in the open coastal areas, protective rip-rap facings of unconsolidated stones, sticks, boards, and posts are largely ineffective in reducing erosion. Rapid erosion and eventual destruction of these devices will occur unless they are constantly maintained and occasionally replaced. More permanent structures likewise require continual maintenance, but also provide greater shoreland protection. One of the specific problems relating to the need for maintaining protective structures is the surficial erosion of red clay bluffs. This tends to undermine and weaken revetment structures, thus quickening the destructive pace of erosion due to wave attack. However, permanent revetments do seem effective in stabilizing bluff areas.

Two groins were constructed during the nineteenth century for the purpose of protecting the entrance to the Duluth ship canal. The primary disadvantage caused by this jetty construction is the blockage of longshore drift of sand southeast of the canal along the bayfront spit. Lakeside property in this area (within 3,000 feet of the canal) is subject to intense wave attack and intermittent flooding due to storm-produced wave action and seiche. In an attempt to replace coastal materials, the U.S. Army Corps of Engineers has intermittently placed dredged materials on this critical erosion area of Minnesota Point. The erosive process is inevitable, and so long as a realization of this fact is kept in mind, the negative consequences can be minimized.

In lower lying embayed areas (St. Louis Bay, Superior Bay, and various harbor slips) protective measures have taken the form of land fill, rip-rap, and breakwater construction to reduce wave action. While these arrangements do lessen the destructive forces of wind and wave, they do little to control flooding which intermittently occurs within the St. Louis River Estuary. Other shoreland modifications include land fill and the skirting of intensively used harbor frontage with concrete slabbing and wood pilings.

Field reconnaissance was undertaken in Spring 1975, after the ice conditions had disappeared for the purpose of locating protective structures and evaluating their conditions and effectiveness. Two sources of information assisted in locating protective structures. First, the Army Corps of Engineers, St. Paul and The Minnesota Department of Natural Resources supplied lists of known structures. The second source of information was the self-administered assessment statements and personal interviews. Data from these two informational sources will be presented in several formats. First, Appendix A contains photographs and a summary description of protective structures. In addition, Table 7 provides an analysis of seven protective structures including their physical condition, effectiveness, and maintenance requirements. In conjunction with Table 7, the seven protective structures are delineated on Plates 2 through 19. Finally, protective action information from the mail-out

and interview responses is summarized and discussed by reach. This information will follow. (See Tables 10,14,16 and 17).

REACH 1

Critical problems are erosion and flooding due to higher water levels, river bank undercutting, surficial erosion of low bluffs, and subsequent river bed deposition. Unfortunately, no information was obtained for protective action in Reach 1 from any of the data sources. Respondents simply failed to provide information. Consequently, no cost figures or effectiveness estimates could be derived.

REACH 2

Critical problems are flooding due to high water levels and storm produced seiche in the harbor area. The questionnaire outlined three separate types of actions totalling about 80 dollars. Actions include fill operations and the placement of protective rip-rap on an existing jetty. When asked about the effectiveness of the operations in retarding erosion and the threat of inundation, two owners failed to reply and the third owner reported his actions as having enjoyed limited success (fair/poor).

REACH 3

Critical problems are flooding on the embayed side of Minnesota Point, aeolian (wind) erosion along the entire expanse of the Point, erosion of beach materials due to storm activity, and the loss of beach nourishment along the groins built to protect the Duluth and Superior harbor ship canals. Minnesota Point is extremely fragile, ecologically. The entire Point consists of easily erodible materials exposed to weathering agents.

A variety of protective actions have been taken to stabilize Minnesota Point landforms and are listed below. The list does not include some methods frequently employed by property owners such as snow-fencing or the vegetating of exposed bluff contours.

Type of Protective Action	# of Actions Taken
Armor the Toe of the Bluff	13
Entrainment of Shore Materials	17
Dissipation of Wave Energy Off-shore	5
Replacement of Beach Materials	1
Modification of Flood Plain	4
Other	9

Total estimated costs were $25,400. Residents who estimated the effectiveness of their protective actions rated them for the most part as being only temporary measures or as having limited (fair/poor) success. Four residents said that their structures had good/excellent results.

REACH 4

The critical problem is that severe storms and wave action during the past two to three years has increased shore damages so that this relatively stable coastal zone is displaying visible evidence of mass wasting and the slumping of bluff materials.

A breakdown of the types of actions taken during the study period is as follows:

Types of Action Taken	# of Actions
Armor the Toe of the Bluff	12
Entrainment of Shore Materials	11
Dissipation of Wave Energy Off-shore	6
Modification of Flood Plain	1
Modification of Flood Plain Structure	1
Other	1

Estimated costs of these shore modifications total 81,500 dollars. Three residents indicated their actions were only of a temporary nature and three said that they had seen no effective results from their efforts. Those who furnished estimates of good/excellent and limited fair/poor results totaled 5 and 18 respectively.

The total costs for protective actions was 107,000 dollars. The average cost per action was $1,391 (mean). Protective action was taken most often in Reach 3 where 49 residents spent an average of 518 dollars. For all of St. Louis County it is estimated that $159,912 was spent by residential parcel owners on protective action during the two year study period. Approximately $135,000 was spent for erosion protection and the remaining $25,000 for flood protection.

Costs of protective action for non-residential parcels totaled 174,000 dollars. The breakdown of these costs is as follows: $10,000 in Reach 1; $59,000 in Reach 2; $102,000 in Reach 3; and $3,000 in Reach 4. Expenditures for structures was $119,000 (See Tables 9 and 15). Costs for other types of protective actions were as follows: relocation $1,800; emergency evacuation $20,000; other 32,700 dollars.

There are about 13 miles of shoreline protected by some form of protective actions. Residential parcels accounted for 1.5 miles of the total, with non-residential comprising the difference of 11.5 miles. About 57 miles of shoreline is unprotected in St. Louis County.

3.0 DAMAGE AREAS AND CONDITIONS

The recent high water levels of Lake Superior have resulted in considerable damages along St. Louis County's North Shore. Almost two-thirds of the residential and non-residential parcels have been subjected

to erosion or flooding during the study period Labor Day 1972 - Labor Day 1974. Erosion was the most prevalent form of damage. About 41 percent of the total 345 residential parcels are affected by shoreline erosion. Flooding affected six percent of the parcels. The combined threat of flooding and erosion affected 16 percent.

Reports of non-residential damage conditions are balanced with 13 of 27 respondents (48%) suffering from erosion, and the remaining 14 (52%) confronted by flooding

Erosion and flood damage information, consisting of personal and real property loss, will be documented based upon data obtained from the self-administered mail-out questionnaire and personal interviews. The response rate to survey instruments was 67 percent for residential parcel owners and 65 percent of non-residential parcel owners.

Damages were sustained to homes, buildings, other structures, and their contents; docks and boathouses; stairways and ramps; grounds and landscaping; and other similar personal property losses. Real property losses include beach and bluff material. Both bank recession and beach area loss are significant physical loss measurements which can be used to document erosion conditions. Briefly summarizing reach losses, it can be shown that Reaches 1 and 2 (embayed areas) are primarily susceptible to the threat of flooding, with both reaches experiencing flooding losses of property. Reaches 3 and 4 (open-coastal areas) are mainly confronted with erosion losses, except the bayside of Minnesota Point (Reach 3) where rather extensive flooding was experienced to both residential and non-residential development.

More specifically, Reach 4, which is predominently residential and the longest of the four reaches, sustained the greatest amount of erosion damage for the two-year study period. Sizeable losses were experienced in terms of real property (bank recession and beach area loss) as well as to personal property.

3.11 FLOOD DAMAGE CONDITIONS AND LOSSES

Inundation was sustained in each of the four reaches of the study area, but was most prevalent in the St. Louis River estuary, the Duluth Harbor, and along the bayside of Minnesota Point. High water levels in conjunction with low lying topography and development conditions has increased the flooding vulnerability of the inner harbor reaches. Flood damage was reported by both residential and non-residential parcel owners and will be discussed by reach.

Residential flooding problems were not reported for either Reaches 1 or 2. In Reach 3, residential flooding has been experienced along the entire bayside shoreline. Problems cited by residents include flooded basements, foundation crackage and seepage, "spongy" lawns and mud bogs, floodwater undermining of docks, boat houses, and the like. Storm induced

conditions from the northeast and southeast were identified as the most prevalent cause of damages. Higher lake levels were often reported as the source of continuous flooding and seepage during later summer and early fall. Flooding damages are outlined in detail in Table 8. Reach 3 sustained the most severe residential flood damage with $109,100 reported.

Reach 4 has experienced only a minimal degree of flooding. The open-coastal shoreline and its shoreforms are more susceptible to erosion action, and this factor probably accounts for the minimized numbers of parcels afflicted by flooding. Few of the Reach 4 homes were severely inundated according to survey results although basement seepage and high ground water levels caused some damages to residences. In this regard, conditions are comparable to the bayside of Minnesota Point where cracked basements, poor drainage, and "spongy" lawn conditions were also reported. Flood damages reported in Reach 4 amounted to 96,900 dollars. The total reported for the residential parcels of the study area was 206,000 dollars.

The extrapolation of residential flood damages for the entire study area was completed for the following damage categories: damage to structures and contents; detached garages and outbuildings, docks and boat houses; stairways and ramps; grounds, landscaping and trees; clean-up costs; septic system damage; loss of rental income; and other damages. Losses were itemized according to the above property conditions and projections were made accordingly. See Table 16 for a detailed analysis of projected damage costs.

The mean damage cost was calculated and projected for each category based on the number of properties subject to flooding. This number was derived from an earlier projection (risk vs no risk of flooding or erosion) and represents those parcels that would be susceptible throughout the study area, based on responses to the self-administered assessment.

It is estimated that flooding damages occuring during Labor Day 1972 through Labor Day 1974 in St. Louis County amounted to 323,000 dollars. Reach 3 accounted for $198,700 while Reach 4 was estimated to have sustained $138,600 in damages.

Non-residential flood damages are more severe than those experienced by residential parcels and were reported in Reaches 1,2 and 3. Flooding damage was not reported by Reach 4 non-residential parcel owners for the two year study period. The only serious flooding in Reach 1 is at the commercial strip in Riverside, in which $46,000 in damage was reported. Reach 2 parcel owners said that they are experiencing flood conditions year-round, especially during the high water cycle in late summer and early fall and when northeasterly storm conditions produce abnormal water levels and excessive wave action. Several parcel owners stated that northeasterly storms are the catalyst of major flood conditions,

and that if lake levels rise an additional 6 to 12 inches, total property and business loss would result. Furthermore, several of the respondents produced letters of testimony submitted to the International Joint Commission at a public hearing held by the Commission in Duluth, Minnesota (Fall 1974), expressing the potential for complete business loss with increased lake levels. It should be noted that docking facility owners favored slightly higher water levels to assure adequate slip depths for marine traffic. Reach 2 property owners reported $349,350 in damages to utilities, commercial and industrial establishments.

Flood damage is also being experienced by Reach 3 non-residential property owners on the bayside near Canal Park and along the lakeside north of the Aerial Bridge toward Michigan Street. The city owned Canal Park area is a prime example of frequent inundation when northeasterly storm conditions occur (See Plate 6). A rock fill has been placed along with rip-rap to combat the extraordinary wave forces. Although this action has been effective in minor storms it is of little deterence when a major storm strikes. Similar conditions are experienced by non-residential parcels located between Canal Park and the beginning of Reach 4. A total of $390,289 in damages was attributed to flooding activity. Reach 3 damages were incurred by utilities, commercial and industrial land uses. Non-residential flood damages for the entire St. Louis County study area totals $785,639 (See Table 9).

3.12 FLOODING EFFECTS ON COMMUNITY SERVICES

Shoreline community services in the Duluth Metropolitan area and outlying vicinities have not suffered any great degree of flood damage. However, some storm drain outlets are now submerged due to higher water levels. Moreover, higher water levels are considered to be responsible for increased turbidity in Lake Superior, which further complicates the sedimentation problem and affects community water supplies.

The Western Lake Superior Sanitary District (WLSSD) provided information about a problem affecting one of its outflow pipes. An interceptor is located on Polk Street and the bayfront of Reach 2. The volume of water inflow into the interceptor system has increased with the higher lake levels to the point of an additional 1,000,000 gallons per day. The pumping costs increased $25-$30 per day, and this has been the case at other such outlets. Moreover, sedimentation is an increasing problem along outflow pipes because they are all now submerged, which was not the case prior to higher lake levels.

3.13 THE 100 YEAR FLOOD PLAIN

In 1974, the Corps of Engineers investigated various methods from which to determine probable flood levels based on available flood level data. The Corps derived 100 year flood levels for the entire United States shoreline of the Great Lakes. The elevations of inundation are based on International Great Lakes Datum (IGLD) 1955, and were prepared on general navigation charts for all lakes.

The 100 year flood plain is outlined on the aerial map mosaics for the entire St. Louis County shoreline. The flood plain for the City of Duluth was derived from a flood plain study recently completed by the City's Planning and Research Department, based on Corps of Engineers' data.

The delineated flood plain area was generally found to extend an average of 200 feet from the water's edge. However, the potential for flooding conditions was more apparent in Reaches 1 and 2, where the harbor flood plain area extended approximately 300 to 500 feet. In Reaches 3 and 4, the only significant variation from the 200 foot average was along the river and creek mouths. Reference should be made to Plates 2 through 19 for the complete shoreline flood plain delineation.

3.21 EROSION DAMAGE CONDITIONS AND LOSSES

As outlined in the prior flood damage section, erosion is the most threatening form of damage in the St. Louis County Study Area with 41 percent of the residential and 48 percent of the non-residential properties subject to damage or risk of erosion. All four reaches experienced erosion damage. The primary factors contributing to unstable shoreline conditions are wave attack, weathering, soils condition, lack of vegetation, relief, and existing development. Erosion is most prominent in the open-coastal water areas of Reach 3 (lakeward side of Minnesota Point) and along most of Reach 4. However, some erosion damage was reported in the inner harbor reach areas.

Erosion damage was reported by both residential and non-residential property owners through the self-administered assessments and subsequent interviewing. The actual damage cost information disclosed by property owners is summarized and presented in Tables 12 and 13 for both residential and non-residential properties. In addition, damage costs are extrapolated for all residential properties subject to erosion, and are presented in Table 17.

Residential property owners in Reaches 2,3 and 4 reported they had suffered erosion damages and estimated loss expenditures. Reach 1 respondents failed to disclose any damage costs and will be excluded from further erosion damage discussion. Erosion damage costs were reported by 120 of 231 respondents for the two-year study period. A total of $323,100 was reported in erosion damages for residential parcels in the St. Louis County Study Area.

Reach 2, which is predominantly non-residential, reported residential erosion damages to grounds and improvements totaling 460 dollars. Reach 3 sustained sizeable losses to grounds and improvements with total damage costs reported to be 32,400 dollars. Meanwhile, Reach 4 reported the greatest amount of damage with 76 respondents reporting damages and expenditures of 290,300 dollars. The magnitude of the damage costs

in Reach 4 reflects the open-coast character of its shoreline and the relative length of the reach. (See Table 12) As was the case in Reach 2 and 3, Reach 4 sustained the largest amount of damage to grounds and improvements ($139,900).

Erosion damage cost projections could not be made for either Reach 1 or 2 because of the lack of data or the small number of reporting units which prevents projection of meaningful figures. However, based on estimates for Reaches 3 and 4, it is extrapolated that erosion damage costs incurred for St. Louis County from Labor Day 1972 through Labor Day 1974 amounted to $455,000 ($320,000 for damages, $135,000 for protective action). Costs for protective action is a significant factor when compared to damage costs.

For non-residential property owners, flooding damages were roughly six times greater than erosion damages. Non-residential parcels in St. Louis County incurred total erosion damages of $119,000 for the two year study period. Cost data could not be revealed by reach for Reaches 1 and 2 in order to avoid disclosure problems. The results for Reaches 1 and 2 are included in the totals for the county. (See Table 13)

Reach 3 experienced the greatest erosion damage loss to non-residential parcels with $109,000 reported for the two year study period. Reach 4, incurred damage costs of 10,000 dollars.

In summary, it is evident that extensive damage costs have been incurred by property owners throughout the county. Losses were particularly heavy in the category of grounds and improvements and most severe in the Reach 4 littoral zone.

3.22 BANK RECESSION AND BEACH AREA LOSS

The St. Louis County Study Area is subject to physical landform losses attributed to high lake level conditions. Survey results indicate that bluff recession and beach area losses have occurred in the study area reaches from Labor Day 1972 through Labor Day 1974. Physical landform information was obtained for residential and non-residential properties through the mail-out self-administered assessments and personal interviewing. In addition, bluff and surf zones profiles were prepared based upon field reconnaissance in the four reach areas. Plates 6, 9, 10, 15, and 19 graphically present bluff profiles, and their locations are pin-pointed on the aerial mosaic plates. Furthermore, soil samples were also taken at each profile site and have been submitted to the Environmental Protection Agency (EPA) for analysis. The results will be included as an addendum to this report at a later date.

Bluff Recession

Bluff recession is a condition in which the toe of the bluff is eroded to a point where little resistance is offered to erosion processes

that act on the bluff-face or embankment. Slumping and mass wasting reduce the bluffs until an equilibrium point is reached between the new toe and bluff-face.

Information on bluff recession in the four reach areas shows that extensive losses have occured in Reach 4 with the remaining reaches experiencing only minimal losses. The following table will describe bluff recession losses by reach for the two year reporting period.

TABLE 4

	RESIDENTIAL	NON-RESIDENTIAL
Reach 1	N/A	N/A
Reach 2	N/A	6.3 feet/year
Reach 3	2.2 feet/year	10.0 feet/year
Reach 4	5.0 feet/year	11.9 feet/year

N/A: Information was not available

Bluff recession in Reach 3 was experienced largely along the lakeside of Minnesota Point where sand dune embankments are found intermittently along the littoral zone. Bluff areas are generally limited in exposure to direct wave attack due to the sizeable beach buffers and attack vulnerable bluff toe areas.

Bluff recession in Reach 4 is quite extensive with an average loss of 5 to 11.9 feet/year. Bluff losses are directly related to wave attack exposure and the red clay soils conditions of the area.

Beach Area

Loss of beach area is a direct result of wave action in which entrained material is transportated along the shore or suspended in the water.

Residential beach area losses were estimated for Reaches 2,3 and 4. Reach 4 losses exceeded the combined totals of beach loss in the other three reaches. Table 11 presents the physical loss analysis by reach.

Reach 2 losses totaled 500 square feet and cannot be considered extremely serious. The Reach 3 sand beach zone experienced losses totaling 47,000 square feet. It should be noted that many of the residential parcels along the lakeside of Minnesota Point are not riparian shoreline owners. The shoreline is actually owned by governmental units. Therefore more beach and bluff loss may be occuring, but it is not documented from the residential data collection effort, and local government officials were not able to provide estimates of such losses.

Reach 4 property owners reported beach area losses of 260,000 square feet. This is a relatively severe problem considering the limited amount of beach area present along Reach 4 during high lake levels. It is not known how much of the loss is permanent. Some of this loss will be regained when lake levels decline.

For the entire St. Louis County Study Area, it is extrapolated that 433,000 square feet of residential beach area was lost to erosion or inundated during the two year study period.

It is readily apparent that bluff recession and beach area losses are a serious problem in the St. Louis County littoral zone. As water levels continue to rise, so do recession rates. Once the water levels reach the toe of the bluff and vulnerable beach area, storm conditions can cause excessive deterioration.

3.23 THE VOLUME OF SEDIMENTS CONTRIBUTED TO LAKE SUPERIOR FROM EROSION PROCESSES

Survey results confirm that the St. Louis County study area has experienced bluff erosion during the two year study period. In several instances erosion processes have undermined bluff faces resulting in the removal and transportation of bluff material. The volume of bluff material eroded during the study period is estimated in Table 11, Physical Erosion Losses, St. Louis County, Labor Day 1972 - Labor Day 1974, as well as on Plates 2-19 (Matrices of residential and non-residential data).

Bluff volume losses were reported in Reaches 2,3 and 4 by 89 of 345 residential parcel owners. Reach 2 had a very minimal loss of 6,000 cubic feet. Reach 3 volume losses were slightly greater with 84,000 cubic feet reported. In Reach 4 exceedingly large losses of 11 million cubic feet of bluff material were reported.

The sizeable losses in Reach 4 can be largely attributed to two major factors; the red clay soil composition and the vulnerability of the reach shoreline to severe wave attack. Glacial red clay deposits common to the south shore of Lake Superior are found in Reach 4. The clay soil is situated on bedrock and is very susceptible to hydraulic erosion processes. The severe open-coastal wave action readily erodes these vulnerable areas resulting in increased sedimentation in Lake Superior. The other three reaches are largely composed of sand and artificial fill materials (embayed areas), and are not subject to intense wave attack thereby restricting excessive erosion and sedimentation contributions to the lake.

It is important to note a commonly held perception. It is the belief that in years past, shore protective structures along portions of Reach 4 were generally unnecessary since water levels were lower. Exceptions to this belief were apparent at those properties which built shore protection devices during the high water period of the early

1950's. (See Appendix A, pp 40-41). As lake levels have risen, property owners in Reach 4 reported they were or had already undertaken protective action in an attempt to alleviate the loss of beach and bluff material. This determination was drawn from interview conversations with residential owners. Many owners emphasized that changing lake levels are becoming an increasing threat to their property.

Non-residential bluff volume losses have also been experienced as interview comments generally indicate an increase in bluff loss over the years. Bluff volume losses were reported in Reaches 2,3 and 4; with Reach 4 contributing the largest sediment load.

Interview respondents estimated bluff material losses of 1 million cubic feet in Reach 2; 480,000 cubic feet in Reach 3; and 4 million cubic feet in Reach 4. Bluff volume losses were not reported in Reach 1 during the interview sessions (See Table 11).

3.24 ACCELERATED EROSION AND ITS EFFECTS ON WATER QUALITY

It is evident from the study's bluff volume loss estimates that soil materials are being eroded, and contribute to sediment levels and turbidity plumes in Lake Superior. The quality of Lake Superior water has been a major topic of research and discussion over the past several years. Research efforts have concluded that erosion conditions are contributing to water quality problems in Lake Superior.

Dr. Michael Sydor, Associate Professor of Physics, University of Minnesota-Duluth, has been monitoring water quality in western Lake Superior for the past several years.[2] Sydor's research is based on the usage of aircraft and satellite imagery (ERTS images) from which turbidity activity has been successfully assessed. Remote sensing for water quality monitoring has provided significant results which will be summarized for the St. Louis County Study Area. Sydor concluded that turbid water in Lake Superior near Duluth is due primarily to shore erosion and resuspension of bottom sediments. Stream input to the Lake is important as a steady source of material. However, this run-off contribution is relatively small as compared to the volumetric contribution of erosion sediments from shore areas. In the referenced report

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[2] Sydor, Michael, Preliminary Evaluation of Red Clay Turbidity Sources for Western Lake Superior, Lake Superior Basin Studies Center, University of Minnesota-Duluth, February 6, 1975.

he states,

> "Examination of ERTS data and ground truth measurements thus far place the contribution to Lake turbidity near Duluth (consisting of particles less than 2 microns in size) as 60% due to shore erosion, 25% due to resuspension, and 15% due to stream runoff. A severe lake plume contains about 10^5 metric tons of red clay material. Plumes of such magnitude are rare, occurring generally in late fall or early spring. Usual storms run 10^4 tons of material per plume."2

Sedimentation in Lake Superior along St. Louis County has affected a number of community services, e.g. 1) the sedimentation of storm sewer outlets; and, 2) the effects on pumping operations along sanitary sewer interceptor pipes which have been submerged due to the higher lake levels. In conjunction with sedimentation, turbidity is causing water quality problems for the cities of Cloquet and Duluth which both draw their domestic water supplies from Lake Superior. Turbidity levels are creating problems at the Cloquet water line intake pipe located two miles from shore on the Lakeside of Minnesota Point (Reach 3) near the Duluth-Superior Entry. (See Plate 9) The location of the Cloquet water supply intake pipe has caused considerable concern because it is drawing highly turbid water a large percentage of the time rendering it unusable for domestic purposes. Several engineering studies were undertaken in an attempt to alleviate this condition. It was concluded that relocation of the intake pipe near the Lakewood Pumping Station or the Federal Water Quality Lab intake pipe would be two viable alternatives. To date no action has been taken to remedy this situation. Dr. Sydor stated that the existing Cloquet intake was supplying water (unfiltered) that was too turbid for drinking water standards 53 percent of the time. Aerial photos and ERTS images show turbid waters remaining in the area of the intake over 50 percent of the time.

The Lakewood Pumping Station has also been confronted with turbidity problems. The pumping station is located in Reach 4 about two miles northeast of Lester River and within the "red clay" soil deposits of the North Shore. (See Plate 14) The Lakewood Pumping Station draws water from an intake that is approximately 1500 feet from shore and 70 feet below the surface (5 feet above the lake bottom). Raw water turbidity statistics were obtained from the City of Duluth Water and Gas Department and are presented on the following page.

TABLE 5

RAW WATER TURBIDITY DATA
LAKEWOOD PUMPING STATION
1972-1974

Year	No. of Pumping Hours	No. of Hrs. Turbidity Recorded	No. of Hours Turbidity - JCU Ranges 1-5	6-10	11-15	16-20	21-30	31-40
1972	5826	3406	3271	108	23	0	0	4
1973	6584	3171	3126	45	0	0	0	0
1974	6639	2489	2458	29	0	2	0	0
Totals	19049	9066	8855	182	23	2	0	4

SOURCE: City of Duluth Water and Gas Department, July 1975.

3.30 EXTENT AND CHARACTER OF AREAS PROTECTED OR NOT SUBJECT TO EROSION AND FLOODING DAMAGE

Throughout the extent of littoral St. Louis County, the variation which exists in shoreforms allows for a wide range of coastal frontage exposures. Several coastal sections within St. Louis County have suffered negligible effects due to flooding or erosion. These coastal sections will be discussed by reach.

REACH 1:

About 3000 feet of the St. Louis River bank is protected by low lying Tallas Island. The protected area forms the estuary bank in section 23 and 24, T49N, R15W. The naturally protected shoreline is undeveloped and wooded, and has experienced very limited loss.

REACH 2:

The entire Reach 2 shoreline is unprotected and susceptible to damages except the sewage treatment plant location, in which a protective dike has been built (1974-1975). The dike spans the shoreline for about 2500 feet.

REACH 3:

Minnesota Point at the terminus between the Superior Entry breakwater and the groins of the Duluth ship canal is a 5 to 6 mile enclosed coastal dune area subject to deposition as well as erosion and flooding conditions. At intermittent locations spanning the shoreline, areas

exist which are not very susceptible to erosion or flooding. In these instances the dune formations are upwards of 30 to 50 feet from the water's edge and are not readily susceptible to damages. Meanwhile, other dunes and bluffs protrude near the water line and are extremely vulnerable to erosion and flooding loss. The exact locations and level of damage susceptibility is too detailed and would require additional field work to document.

REACH 4:

There are two coastal areas in Reach 4 that have experienced negligible damages during the two year study period. First, a short 1000 foot segment of Leif Erickson Park (12th Avenue East) is a non-erodible low bluff area composed of an erosion resistant intrusive bedrock formation. The width of beach zone and resistant bedrock escarpment minimize damage in this area. Secondly, from approximately 16th Avenue East in Duluth to 45th Avenue East (2.5 miles) the same type of shoreline exists. The beach zone and erosion resistant bedrock formulates a naturally protective barrier at the present water levels. Although erosion is recognized as a natural process, coastal zone areas such as these are largely resistant to this degradation mechanism.

4.0 RECREATIONAL AND ENVIRONMENTAL LOSSES

4.1 BEACH RECREATION AND RECREATIONAL BOATING

The study design for the survey did not include the collection of quantitative data for these specific types of uses. Parameters such as man-hours or recreation days lost due to the recent high water period were not used. Estimates of total cost for repair of damage to facilities was received voluntarily from several riparian owners, but these are only estimates and are not subject to a statistical analysis. Therefore, only a general discussion of these types of losses is possible.

Examples of losses reported are: the owner-manager of Lake-head Basin spent a considerable sum for sheet piling and fill to prevent further erosion of boat moorings, yard and under the building.

Drill's Marina in Duluth has been forced to raise the pier, docks and power boxes by three feet.

These two interviews with private dock and beach operators exemplify the lack of quantitative data. Similar problems with incomplete data were encountered in the responses from public land owners and managers. The softball fields at the end of Park Point have had a severe problem in the scheduling of games, due to the elevated water table resulting in standing water. In 1973, the fields at Park Point were raised but the problem still exists, and playoff games in the late summer of 1974 had to be cancelled.

From the Lester River in eastern Duluth to the city limits, approximately five miles, the City of Duluth owns almost all of the shoreline. Estimates of dollar values were not available. Park officials reported increased shoreline erosion with attendant tree loss due to the slumping of banks. This slumping also cuts into the available upland for picnic sites.

Many instances of total beach flooding and resulting debris deposition were noted, which contribute to a great reduction of suitable swimming beaches, as well as those beaches which are more suitable for rock collecting, picnicking and camping.

4.2 ENVIRONMENTAL AREAS

High lake levels allow increased wave attack of the natural shoreline and man's protection structures. Shore vegetation, sediments, and debris from destroyed structures is removed during storm activity. As the storms subside, large amounts of debris are deposited on shoreline properties. The increased removal and deposition activity that has occured during the recent high lake levels has caused higher maintenance and sanitation costs at public facilities, such as Canal Park and Chambers Grove. A similar problem of general shoreline blight is occuring over the remainder of the shore in the area.

Another aesthetic problem is the visual scars which result from bluff erosion. Numerous areas where the wave action and water levels have undercut the soil bluff, trees have been undermined. This has resulted in leaning and fallen trees which mar the faces of the bluff and litter the shoreline. This situation detracts from the aesthetic qualities of this otherwise scenic area.

5.0 CONCLUSIONS

This pilot study was conducted of St. Louis County shoreland damages caused by or directly related to the 1972-1974 high water period on the Great Lakes. Damage information, consisting of personal and real property loss and their associated costs, has been documented based on self-administered assessments, personal interviews and field reconnaissance. St. Louis County's North Shore riparian owners were cooperative and eager to provide information. The response rates to survey instruments was 67 percent for residential owners and 65 percent for non-residential parcel owners. About two-thirds of the residential and non-residential parcels have been subject to either erosion or flooding during the two year study period.

Summarizing reach area losses, Reaches 1 and 2 (embayed areas) were primarily susceptible to the threat of flooding, and both reaches documented flooding losses of personal and real property. Reaches 3 and 4 were mainly confronted with erosion losses, exept the bayside of

Minnesota Point (Reach 3) where extensive flooding was experienced to residential and non-residential development. Reach 4, which is predominantly residential and the longest of the four reaches, sustained the greatest amount of erosion damage for the two-year period. Reach 4 experienced sizeable losses of real property in terms of bank recession and beach area loss. It also received extensive damages to personal property. Both Reaches 3 and 4 will continue to experience additional losses as long as the high lake levels continue and accelerated erosion processes associated with such conditions are present.

The following is a summary of erosion and flooding damage costs experienced by both residential and non-residential parcels of the study area.

ST. LOUIS COUNTY
REPORTED DAMAGE COSTS
LABOR DAY 1972 - LABOR DAY 1974

	Residential	Non-Residential
Erosion Damage	$323,100	$119,400
Flooding Damage	206,000	785,000
	$529,100	$905,000

ST. LOUIS COUNTY
EXTRAPOLATED DAMAGE COSTS
LABOR DAY 1972 - LABOR DAY 1974

	Residential	Non-Residential
Erosion Damage	$454,700	$119,400
Flooding Damage	323,300	785,000
	$778,000	$905,000

Non-residential damages were not extrapolated for the St. Louis County study area. All non-residential damage costs were based on those reported during personal interviews for which a 100 percent canvass was attempted. The methods for extrapolating data were designed specifically to address damage estimates for non-respondent owners of residential parcels. Extrapolation of residential damage values were derived from projections based on actual reported damages.

TABLE 6

SUMMARY OF GREAT LAKES SHORELINE USE, OWNERSHIP, AND VALUE

ST. LOUIS COUNTY LABOR DAY 1972-1974

SHORELAND USE	MILES/SHORELAND	OWNERSHIP				AVERAGE ASSESSMENT VALUE/ FRONT FOOT
		FEDERAL	STATE	LOCAL	PRIVATE	
REACH 01	TOTAL 7.5	NONE	1.78	2.01	3.71	6.52/ft.
Residential	0.23					
Commercial	0.68					
Industrial	0.11					
Manufacturing	1.17					
Utilities	---					
Agric./Forest & Undeveloped	1.82					
Tax-exempt	3.49					
REACH 02	TOTAL 25.9	NONE	2.69	1.72	21.49	105.94/ft.
Residential	0.27					
Commercial	0.06					
Industrial	12.45					
Manufacturing	1.48					
Utilities	1.59					
Agric./Forest & Undeveloped	5.64					
Tax-exempt	4.41					

Source: St. Louis County/City of Duluth tax records 1974.

TABLE 6 (Cont.)

SUMMARY OF GREAT LAKES SHORELINE USE, OWNERSHIP, AND VALUE

ST. LOUIS COUNTY LABOR DAY 1972-1974

SHORELAND USE	MILES/SHORELAND	OWNERSHIP				AVERAGE ASSESSMENT VALUE/ FRONT FOOT
		FEDERAL	STATE	LOCAL	PRIVATE	
REACH 03	TOTAL 17.15	1.72	2.45	7.66	5.32	42.01/ft.
Residential	1.57					
Commercial	0.28					
Industrial	1.17					
Manufacturing	0.82					
Utilities	0.35					
Agric./Forest & Undeveloped	1.33					
Tax-exempt	11.63					
REACH 04	TOTAL 19.32	NONE	0.45	6.0	12.87	19.38/ft.
Residential	3.94					
Commercial	0.45					
Industrial	0.11					
Manufacturing	---					
Utilities	---					
Agric./Forest & Undeveloped	8.37					
Tax-exempt	6.45					

Source: St. Louis County/City of Duluth tax records 1974.

TABLE 7

ANALYSIS OF SHORE PROTECTION STRUCTURES

ST. LOUIS COUNTY LABOR DAY 1972-Labor Day 1974

REACH LOCATION	MAP NUMBER REFERENCE	TYPE OF STRUCTURE	CONDITION	MAINTENANCE REQUIREMENT	EFFECTS OF SHORELINE STABILIZATION
REACH 02	4	BREAKWATERS	EXCELLENT	NONE	NOT APPLICABLE
REACH 03	6	GROINS, JETTIES	EXCELLENT	OCCASIONAL	PERMANENT
REACH 03	7	BEACH NOURISHMENT	EXCELLENT	OCCASIONAL	PERMANENT
REACH 03	7	OPERATION FORESIGHT	OCCASIONAL	OCCASIONAL	LIMITED
REACH 04	17	REVETMENTS	OCCASIONAL	OCCASIONAL	LIMITED
REACH 04	15	REVETMENTS	CONSTANT	OCCASIONAL	LIMITED
REACH 04	15	SEAWALLS, BULKHEADS	OCCASIONAL	OCCASIONAL	LIMITED

Source: U. S. Army Corps of Engineers, St. Paul District; Minnesota Department of Natural Resources
The above structures have received permits and were evaluated in the field, during the spring of 1975.

TABLE 8: SUMMARY OF RESIDENTIAL PROPERTY FLOOD DAMAGES ST. LOUIS COUNTY LABOR DAY 1972 LABOR DAY 1974

Reporting Unit	Total Costs ($000)	Erosion Damage by Source				Cost of Protection				Financial Losses
		Structure* and Contents ($000)	Grounds and Improvements ($000)	Clean Up ($000)	Other Damages ($000)	Costs of Relocation ($000)	Cost of Protective Structures ($000)	Costs of Emergency Evacuation ($000)	Other Costs ($000)	Net Loss of (Rental) Income ($000)
St. Louis County	206.0	66.7	80.6	7.5	34.5	N/A	16.7	N/A	0	N/A
Reach 01	N/A	---	---	---	----	---	----	---	-	---
Reach 02	N/A	---	---	---	----	---	----	---	-	---
Reach 03	109.1	56.3	26.9	2.8	10.9	N/A	12.2	N/A	0	N/A
Reach 04	96.9	10.4	53.7	4.7	23.6	N/A	4.5	N/A	0	N/A

*The total includes detached garages and outbuildings, docks and boathouses, and stairways and ramps

N/A Not Applicable or No Response

TABLE 9: SUMMARY OF NONRESIDENTIAL PROPERTIES: FLOOD LOSSES - MONETARY COSTS LABOR DAY 1972 - LABOR DAY 1974

REPORTING UNIT AND LAKESHORE ACTIVITY	TOTAL** COSTS ($000)	FLOOD DAMAGES BY SOURCE				COSTS OF PROTECTION				FINANCIAL LOSSES
		STRUCTURE & CONTENTS ($000)	GROUNDS & IMPROVEMENT ($000)	CLEAN UP ($000)	OTHER DAMAGES ($000)	COSTS OF RELOCATION ($000)	COSTS OF PROTECTIVE STRUCTURES	COSTS OF EMERGENCY EVACUATION	OTHER COSTS ($000)	NET LOSS OF BUSINESS INCOME ($000)
ST. LOUIS COUNTY	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
Commercial/Industrial	441.4	283.4	8.3	36.8	8.0	1.8	32.0	20.0	15.3	36.0
Transportation	N/A									
Utilities	344.2	293.9	0	40.0	0	0	10.3	0	0	0
Tax Exempt	N/A									
REACH 01										
Commercial/Industrial	46. 0	12.0	0	4.0	0	0	10.0	0	0	20.0
Transportation	N/A									
Utilities	N/A									
REACH 02										
Commercial/Industrial	349.1	232.0	7.5	26.9	8.0	1.8	21.6	20.0	15.3	16.0
Transportation	N/A									
Utilities	+	0	0	0	0	0	+	0	0	0
REACH 03										
Commercial/Industrial	46.4	39.0	+	5.9	0	0	+	0	0	0
Transportation	N/A									
Utilities	343.9	293.9	0	40.0	0	0	10.0	0	0	0
REACH 04										
Commercial/Industrial	N/A									
Transportation	N/A									
Utilities	N/A									

+ These are positive damage costs totaling less than $1000. N/A: Not applicable or no response.

** Differences in row totals is attributed to rounding to the nearest $100.00

TABLE 10: ALL LAKESHORE PROPERTIES: FLOOD LOSSES - MONETARY COSTS LABOR DAY 1972 - LABOR DAY 1974

REPORTING UNIT AND LAKESHORE ACTIVITY	TOTAL** COSTS ($000)	FLOOD DAMAGES BY SOURCE				COSTS OF PROTECTION				FINANCIAL LOSSES
		STRUCTURE & CONTENTS ($000)	GROUNDS & IMPROVEMENT ($000)	CLEAN UP	OTHER DAMAGES	COSTS OF RELOCATION	COSTS OF PROTECTIVE STRUCTURES	COSTS OF EMERGENCY EVACUATION	OTHER COSTS ($000)	NET LOSS OF BUSINESS INCOME ($000)
ST. LOUIS COUNTY										
Residential Properties	206.3	66.7	80.6	7.5	34.4	N/A	16.7	N/A	0	N/A
Nonresidential Properties	785.6	577.4	8.3	76.8	8.0	1.8	42.3	20.0	15.3	36.0
REACH 01										
Residential Properties	N/A									
Nonresidential Properties	46.0	12.0	N/A	4.0	N/A	N/A	10.0	N/A	N/A	20.0
REACH 02										
Residential Properties	N/A									
Nonresidential Properties	349.4	232.0	7.5	26.9	8.0	1.8	21.9	20.0	15.3	16.0
REACH 03										
Residential Properties	109.1	56.3	26.9	2.8	10.9	N/A	12.2	N/A	0	N/A
Nonresidential Properties	390.3	333.3	+	45.9	N/A	N/A	10.6	N/A	N/A	N/A
REACH 04										
Residential Properties	96.9	10.4	53.7	4.7	23.6	N/A	4.5	N/A	0	N/A
Nonresidential Properties	N/A									

+These are positive damage costs totaling less than $1000. N/A: Not applicable or no response.
** Differences in row totals is attributed to rounding to the nearest $100.00.

TABLE 11: PHYSICAL EROSION LOSSES ST. LOUIS COUNTY LABOR DAY 1972-Labor Day 1974

REPORTING UNIT	PHYSICAL LOSSES								
	AMOUNT OF BEACH AREA LOST (000sq.ft)	AMOUNT OF BLUFF VOLUME LOST (000cu.ft	NUMBER OF RESIDENCES LOCATED WITHIN __ FEET OF EDGE OF BLUFF						NUMBER OF RESIDENCES DESTROYED
			0-25	26-50	51-75	76-100	101-150	151-200	
RESIDENTIAL	307	11,090	27	36	18	16	6	15	N/A
REACH 01	D	D	D	D	D	D	D	D	N/A
REACH 02	.5	6	D	D	D	D	D	D	N/A
REACH 03	47	84	10	15	1	1	N/A	N/A	N/A
REACH 04	260	11,000	17	20	17	15	6	15	N/A
NON-RESIDENTIAL	156	5,050	N/A	N/A	N/A	N/A	N/A	N/A	N/A
REACH 01	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
REACH 02	62.5	1,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A
REACH 03	30	50	N/A	N/A	N/A	N/A	N/A	N/A	N/A
REACH 04	64	4,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A

D - IN ORDER TO MAINTAIN THE CONFIDENTALITY OF THE SURVEY DATA, WHEN THE NUMBER OF RESPONSES IS LESS THAN 2, INFORMATION IS NOT DISCLOSED.

N/A - NOT APPLICABLE OR NO RESPONSE.

TABLE 12: SUMMARY OF RESIDENTIAL PROPERTY EROSION DAMAGES ST. LOUIS COUNTY LABOR DAY 1972 - LABOR DAY 1974

REPORTING UNIT	TOTAL** COSTS ($000)	EROSION DAMAGES BY SOURCE				COSTS OF PROTECTION				FINANCIAL LOSSES
		STRUCTURE & CONTENTS* ($000)	GROUNDS & IMPROVEMENT ($000)	CLEAN UP ($000)	OTHER DAMAGES ($000)	COSTS OF RELOCATION ($000)	COSTS OF PROTECTIVE STRUCTURES	COSTS OF EMERGENCY EVACUATION	OTHER COSTS ($000)	NET LOSS OF INCOME ($000)
ST. LOUIS COUNTY	323.1	28.0	151.1	4.7	48.8	N/A	90.4	N/A	N/A	N/A
REACH 01	0	0	0	0	0	N/A	N/A	N/A	N/A	N/A
REACH 02	+	0	+	0	0	N/A	+	N/A	N/A	N/A
REACH 03	32.4	7.4	11.0	+	0	N/A	13.2	N/A	N/A	N/A
REACH 04	290.3	20.6	139.9	4.0	48.8	N/A	77.0	N/A	N/A	N/A

N/A: Not applicable or no response
+: These are positive damage costs totaling less than $1000.

*The total includes detached garages and out buildings, docks and boathouses, and stairways and ramps.

**Difference in row totals is attributed to rounding to the nearest $100.00.

TABLE 13: SUMMARY OF NONRESIDENTIAL PROPERTY EROSION DAMAGES ST. LOUIS COUNTY LABOR DAY 1972 - LABOR DAY 1974

REPORTING UNIT AND LAKESHORE ACTIVITY	TOTAL** COSTS ($000)	EROSION DAMAGES BY SOURCE				COSTS OF PROTECTION				FINANCIAL LOSSES
		STRUCTURE & CONTENTS ($000)	GROUNDS & IMPROVEMENT ($000)	CLEAN UP ($000)	OTHER DAMAGES ($000)	COSTS OF RELOCATION ($000)	COSTS OF PROTECTIVE STRUCTURES	COSTS OF EMERGENCY EVACUATION	OTHER COSTS ($000)	NET LOSS OF BUSINESS INCOME ($000)
ST. LOUIS COUNTY										
Commercial/Industrial	N/A									
Manufacturing	119.4	11.0	8.0	0	0	0	77.0	0	17.4	6.0
Utilities	N/A									
REACH 01										
Commercial/Industrial	N/A									
Manufacturing	N/A									
Utilities	N/A									
REACH 02										
Commercial/Industrial	N/A									
Manufacturing	N/A									
Utilities	N/A									
REACH 03										
Commercial/Industrial	N/A									
Manufacturing	109.0	11.0	0	0	0	0	75.0	0	17.0	6.0
Utilities	N/A									
REACH 04										
Commercial/Industrial	N/A									
Manufacturing	10.4	0	8.0	0	0	0	2.0	0	+	0
Utilities	N/A									

N/A: Not applicable or no response

+: These are positive damage costs totaling less than $1000.

** Differences in row totals is attributed to rounding to the nearest $100.00.

TABLE 14: TOTAL EROSION DAMAGES ST. LOUIS COUNTY LABOR DAY 1972 - LABOR DAY 1974

REPORTING UNIT	TOTAL*** COSTS ($000)	EROSION DAMAGES BY SOURCE				COSTS OF PROTECTION				FINANCIAL LOSSES
		STRUCTURE* & CONTENTS ($000)	GROUNDS** & IMPROVEMENT ($000)	CLEAN UP ($000)	OTHER DAMAGES ($000)	COSTS OF RELOCATION ($000)	COSTS OF PROTECTIVE STRUCTURES	COSTS OF EMERGENCY EVACUATION	OTHER COSTS ($000)	NET LOSS OF (Rental) INCOME ($000)
ST. LOUIS COUNTY										
RESIDENTIAL PROPERTIES	323.1	28.0	151.9	4.7	48.8	N/A	90.4	N/A	0	N/A
NONRESIDENTIAL PROPERTIES	119.4	11.0	8.0	N/A	N/A	N/A	77.0	N/A	17.0	6.0
REACH 01										
RESIDENTIAL PROPERTIES	0	0	0	0	0	N/A	N/A	N/A	0	N/A
NONRESIDENTIAL PROPERTIES	N/A									
REACH 02										
RESIDENTIAL PROPERTIES	+	0	+	0	0	N/A	+	N/A	0	N/A
NONRESIDENTIAL PROPERTIES	N/A									
REACH 03										
RESIDENTIAL PROPERTIES	32.4	7.4	11.0	+	0	N/A	13.2	N/A	0	N/A
NONRESIDENTIAL PROPERTIES	109.0	11.0	N/A	N/A	N/A	N/A	75.0	N/A	17.0	6.0
REACH 04										
RESIDENTIAL PROPERTIES	290.3	20.6	139.9	4.0	48.8	N/A	77.0	N/A	0	N/A
NONRESIDENTIAL PROPERTIES	10.4	N/A	8.0	N/A	N/A	N/A	2.0	N/A	+	N/A

*Includes damage to structures and contents, detached garages and out building, docks and boathouses, and stairway and ramps.
**Includes damage to grounds landscaping and trees, and clean up costs. +These are damage costs totaling less than $1000.
***Differences in row totals is attributed to rounding to the nearest $100.00. N/A: Not applicable or no response.

TABLE 15: SUMMARY OF NON-RESIDENTIAL EROSION AND FLOOD DAMAGES ST. LOUIS COUNTY LABOR DAY 1972 - LABOR DAY 1974

REPORTING UNIT AND LAKESHORE ACTIVITY	TOTAL** COSTS ($000)	DAMAGES BY SOURCE				COSTS OF PROTECTION				FINANCIAL LOSSES
		STRUCTURE & CONTENTS ($000)	GROUNDS & IMPROVEMENT ($000)	CLEAN UP ($000)	OTHER DAMAGES ($000)	COSTS OF RELOCATION ($000)	COSTS OF PROTECTIVE STRUCTURES	COSTS OF EMERGENCY EVACUATION	OTHER COSTS ($000)	NET LOSS OF BUSINESS INCOME ($000)
ST. LOUIS COUNTY										
Commercial/Industrial & Manufacturing	560.8	294.4	16.3	36.8	8.0	1.8	109.0	20.0	32.7	42.0
Utilities	344.2	293.9	0	40.0	0	0	10.3	0	0	0
REACH 01										
Commercial/Industrial & Manufacturing	46.0	12.0	0	4.0	0	0	10.0	0	0	20.0
Utilities	N/A									
REACH 02										
Commercial/Industrial & Manufacturing	349.1	232.0	7.5	26.9	8.0	1.8	21.6	20.0	15.3	16.0
Utilities	+	0	0	0	0	0	+	0	0	0
REACH 03										
Commercial/Industrial & Manufacturing	155.4	50.4	+	5.9	0	0	75.4	0	17.0	6.0
Utilities	343.9	293.9	0	40.0	0	0	10.0	0	0	0
REACH 04										
Commercial/Industrial & Manufacturing	10.4	0	8.0	0	0	0	2.0	0	+	0
Utilities	N/A									

+ These are positive damage costs totaling less then $1000. N/A: Not applicable or no response.

** Differences in row totals is attributed to rounding to the nearest $100.00.

TABLE 16: EXTRAPOLATION OF RESIDENTIAL PROPERTY FLOOD DAMAGE ST. LOUIS COUNTY LABOR DAY 1972 - LABOR DAY 1974

REPORTING UNIT	TOTAL COSTS ($000)	FLOOD DAMAGES BY SOURCE				COSTS OF PROTECTION				FINANCIAL LOSSES
		STRUCTURE & CONTENTS* ($000)	GROUNDS & IMPROVEMENT ($000)	CLEAN UP ($000)	OTHER DAMAGES ($000)	COSTS OF RELOCATION ($000)	COSTS OF PROTECTIVE STRUCTURES	COSTS OF EMERGENCY EVACUATION	OTHER COSTS ($000)	NET LOSS OF (RENTAL) INCOME ($000)
St. Louis County	323.3	110.5	123.4	11.5	52.9	N/A	24.9	N/A	0	N/A
REACH 01	N/A									
REACH 02	D									
REACH 03	188.4	98.3	47.6	4.8	19.5	N/A	18.2	N/A	0	N/A
REACH 04	134.8	12.2	75.8	6.7	33.4	N/A	6.7	N/A	0	N/A

N/A Not applicable or no response

D: In order to maintain the confidentality of survey data, when the number of responses is less than 2, information is not disclosed.

*: Includes damage to structure and contents, detached garages and out buildings, docks and boathouses, and stairways and ramps.

TABLE 17: EXTRAPOLATION OF RESIDENTIAL PROPERTY EROSION DAMAGES ST. LOUIS COUNTY LABOR DAY 1972 - LABOR DAY 1974

REPORTING UNIT	TOTAL** COSTS ($000)	EROSION DAMAGES BY SOURCE				COSTS OF PROTECTION				FINANCIAL LOSSES
		STRUCTURE & CONTENTS* ($000)	GROUNDS & IMPROVEMENT ($000)	CLEAN UP ($000)	OTHER ** DAMAGES ($000)	COSTS OF RELOCATION ($000)	COSTS OF PROTECTIVE STRUCTURES	COSTS OF EMERGENCY EVACUATION	OTHER COSTS ($000)	NET LOSS OF (RENTAL) INCOME ($000)
COUNTY: ST. LOUIS	454.6	37.5	209.8	6.6	66.0	N/A	134.7	N/A	N/A	N/A
REACH 01	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
REACH 02	D	D	D	D	D	N/A	D	N/A	N/A	N/A
REACH 03	53.0	12.7	19.3	1.3	N/A	N/A	19.7	N/A	N/A	N/A
REACH 04	401.6	24.8	190.5	5.3	66.0	N/A	115.0	N/A	N/A	N/A

N/A: Not applicable or no response
*Includes damage to structure and contents, detached garages and out buildings, docks, and boathouses, and stairways and ramps.

D: In order to maintain the confidentiality of the survey data, when the number of responses is less than 2, information is not disclosed.
** Differences in row totals is attributed to rounding to the nearest $100.00.

APPENDIX A

A LOOK AT SHORE PROTECTIVE STRUCTURES

Figure A-1 Fill Area: Location is in Reach 2
Physical Shoreform: Low bluff erodible, no beach.

Exposure to wave climate: embayment moderate. Action was taken during 1974 to fill a no longer used sluice. Although not directly linked with shoreline erosion damage, this measure did include an upgrading of the shoreform by armoring the toe of the bluff.

Figure A-2 Groins: Location is on the embayed portion of Reach 3.
Physical shoreform: Low-plain erodible, no beach.

Exposure to wave climate: Embayment low. This enclosing groin was built during 1972 to provide an erosion check at particularly vulnerable section of beach on Minnesota Point. Construction materials were of stone, rock, and broken concrete. Length of constructed groins totals approximately 800 feet.

Figure A-3 Offshore breakwaters: Location is the embayed shore of Minnesota Point (Reach 3).
Physical shoreform: Low-bluff, erodible, with beach.

Exposure to wave climate: Embayment moderate. This action was taken in an effort to trap sediments by the filling in of the beach area with a less erodible material. Construction of stock consisted of stone, rock, sand, and gravel. Approximate length of this breakwater is between 100 and 200 feet.

Figure A-4 Protective rip-rap: Location is embayment side of Reach 3.
Physical shoreform: Low bluff erodible, no beach.

Exposure to wave climate: Embayment low. Construction materials for this structure consist mainly of pre-cast concrete shapes reinforced with small boulders. Property owner listed this action as having had limited effect but requiring little maintenance or cost expenditure.

Figure A-5 Stone seawall, location is in Reach 4.
Physical shoreform: Erodible bluff over bedrock with beach.

Exposure to wave climate: Open coast, high wave climate. This bulkhead was built in two sections, the original one finished in 1950 and the addition being completed in 1967. Length of wall is just over 200 feet. Owner of this property rated this device as having had limited effect with some damage to the older sections of the wall.

Figure A-6 Stone revetment: Reach 4 location.
Physical shoreform is on erodible bluff over bedrock, with beach.

Exposure to wave attack: Open coast, high wave climate. Note damage to this structure caused by lake storm activity. Revetments such as this are inexpensive to construct and effective so long as they remain in good condition. However, they do require periodic maintenance and subsequently lose effectiveness rapidly if they are neglected.

Figure A-7 Concrete revetment, Reach 4 location.
Physical shoreform: Erodible low-bluff over bedrock, with beach.

Exposure to wave attack: Open coast, high wave climate. This bulkhead was constructed in 1955 of pre-cast concrete blocks. It is nearly fifty feet long. Some deterioration in structure is noted, primarily with regard to the caulking of the cement blocks. Overall effectiveness of this device is good.

APPENDIX A
SHORE PROTECTIVE STRUCTURES

Figure A-1

Figure A-2

APPENDIX A
SHORE PROTECTIVE STRUCTURES

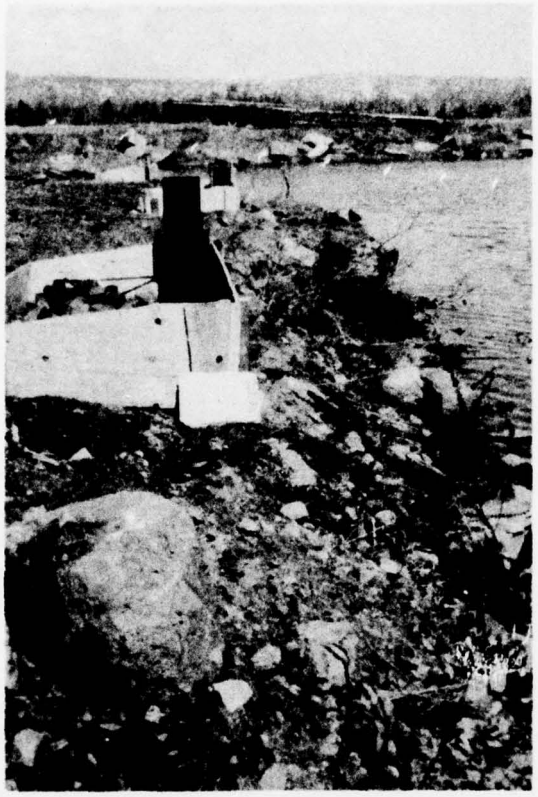


Figure A-3

Figure A-4

APPENDIX A
SHORE PROTECTIVE STRUCTURES

Figure A-5

APPENDIX A
SHORE PROTECTIVE STRUCTURES

Figure A-6

Figure A-7

APPENDIX B

FIELD RECONNAISSANCE OF EROSION DAMAGE: ST. LOUIS COUNTY SHORELINE

Throughout the discussion of the erosion problems existent along the St. Louis County shoreline, the attempt has been to illustrate and define the problem by narrative. This photo section deals with the issue more emphatically, presenting a vivid portrait of natural processes at work. Reach 4 is the area under consideration. As presented in the physical reach description and plates 10-19, Reach 4 is exposed to an open wave climate and is characterized by a low-bluff erodible shoreline. The only exception is the shoreline expanse labled low-bluff non-erodible between 14th Avenue East and 31st Avenue East in Duluth. The following photos will portray existing damage conditions along portions of the Reach 4 shoreline.

Figure B-1 Storm damage to wooden dock located on embayed side of Reach 3. Note evidence of high water marks and storm surge precipitated by high wave activity.

Figure B-2 Makeshift protective armoring in the 9,000 block of eastern Duluth. Such structures have very limited effectiveness when exposed to the type of strong oscillatory wave action present on Lake Superior during lake squalls.

Figure B-3 Exposed clay bluffs located in vicinity of Lakewood Pumping Station. Particularly critical here are the erosion phenomena known as slumping and mass wasting. The consolidated clay bluffs becoming undermined by storm wave and lake surge develop a physical or structural imbalance. Nature's attempt to balance these gravitational stresses leads to a displacement of bluff materials downward to the beach where they are washed away. A newly-cut bluff results, and the process begins anew. Surficial run-off also plays an important role in this landward cycle of coastal bluff retreat.

Figure B-4 Approaching the Stoney Point area, we find a vulnerable erosion area. A roadside park area and even the roadway itself are being placed in jeopardy by the retreat of shoreforms.

Figure B-5 Despite the beneficial presence of forest and tree cover over large portions of the Reach 4 expanse, the landward march of North Shore clay bluffs continues. Here the mass wasting and creep of beach materials has caused slumping and the lakeward migration of littoral vegetation and forest species. One curious end product of some value to collectors results from this process - driftwood.

Figure B-6 An excellent example of bluff undermining. Note driftwood at base of the bluff toe and the various sorted pebbles and stones left awash on the beach by storm wave activity. Near Sucker River outlet, an area of poorly consolidated fluvial low-bluff clays exists. The Sucker River is known for the high load of graded particles it transports and the downcutting of its stream bed.

Figure B-7 Exposed coastal bluffs, extremely vulnerable to wave attack and showing evidence of that attack. Note that vegetation is lacking on the lakeward bluff slopes and exposed contours.

Figure B-8 A fine example of the lake terrace beach creep phenomena. Evidence of the undercutting of sod exists here when judged by the presence of beach overhang of these matted grass carpets and their extensive root system.

Figure B-9 Washout of unconsolidated soil materials behind bedrock breakers of slightly higher elevation has created this mere. Regression of the shoreform here is slowed, since the transport of loosened sediments from the mere is largely prevented by breakwater effect from the wave-built bench.

Fibure B-10 Erosion and slump of bluff materials adjacent to old U.S. Highway 61 (North Shore Drive). Although critical problems such as this exist elsewhere on the Great Lakes, the intensity and frequency of such conditions on Lake Superior are just approaching the serious proportions of its smaller counterparts.

APPENDIX B
GENERAL FIELD RECONNAISSANCE

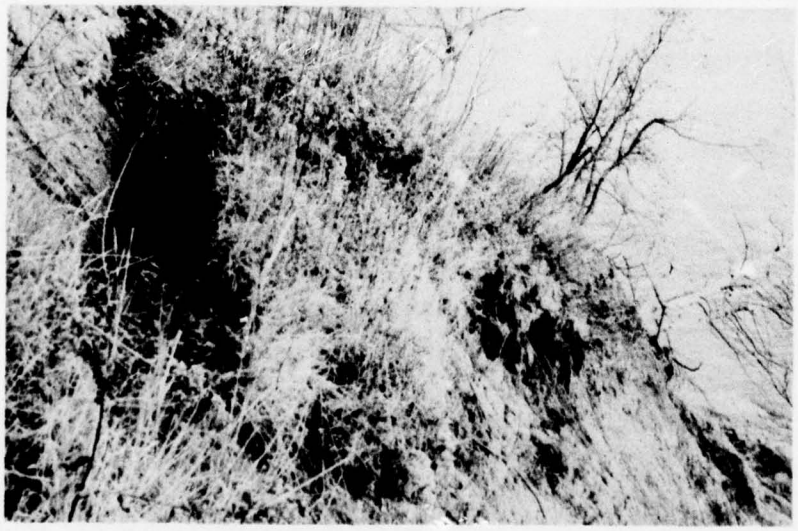
Figure B-1

APPENDIX B
GENERAL FIELD RECONNAISSANCE

Figure B-2

APPENDIX B
GENERAL FIELD RECONNAISSANCE

Figure B-3

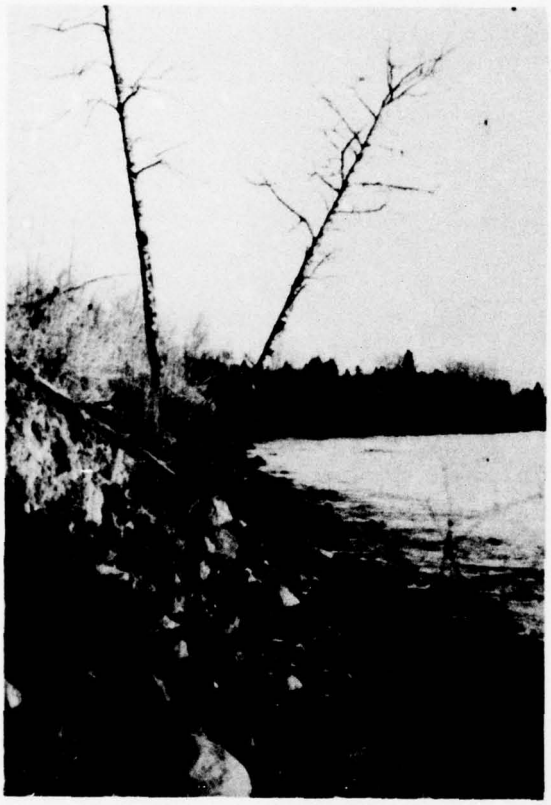


APPENDIX B
GENERAL FIELD RECONNAISSANCE

Figure B-4

APPENDIX B
GENERAL FIELD RECONNAISSANCE

Figure B-5



APPENDIX B
GENERAL FIELD RECONNAISSANCE

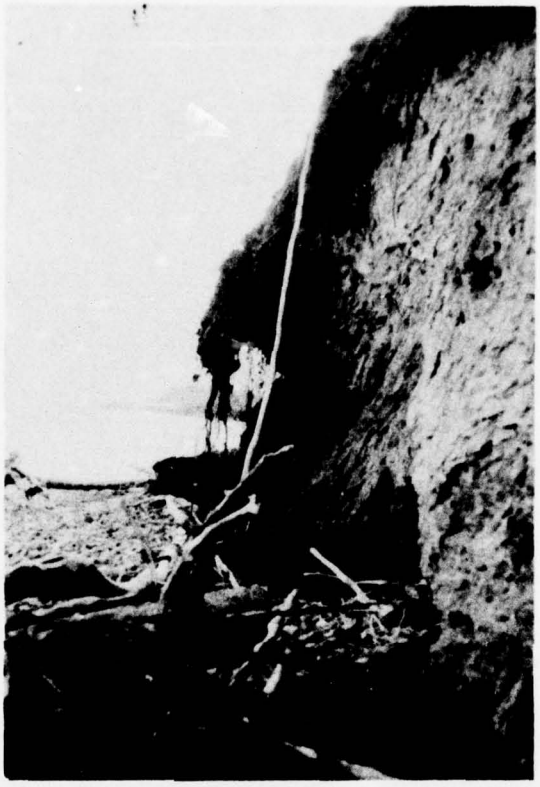


Figure B-6

Figure B-7

Figure B-7 (cont.)

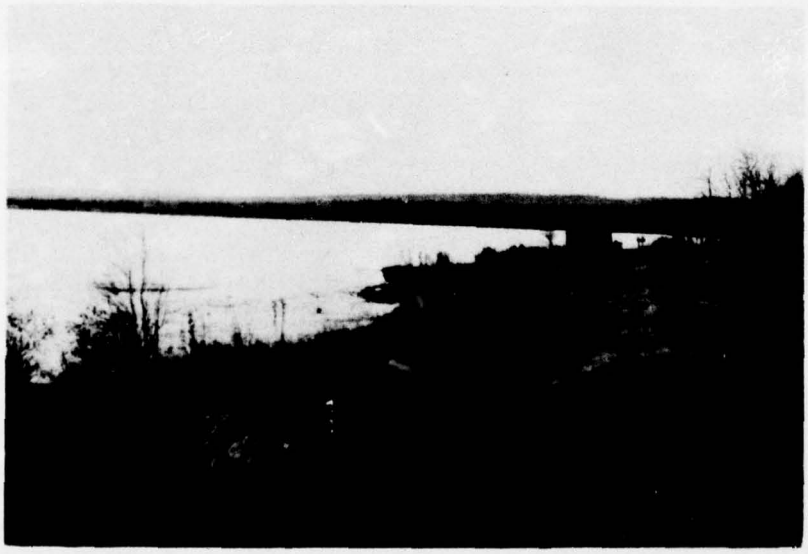


Figure B-8

APPENDIX B
GENERAL FIELD RECONNAISSANCE

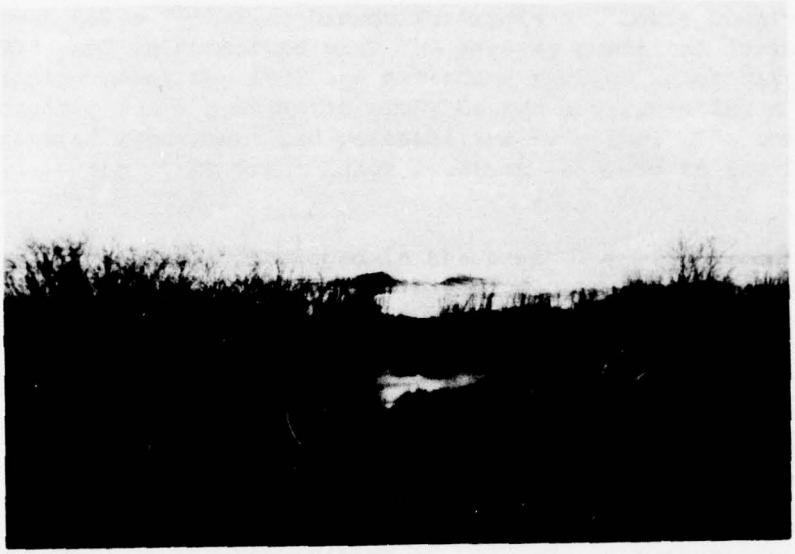


Figure B-9

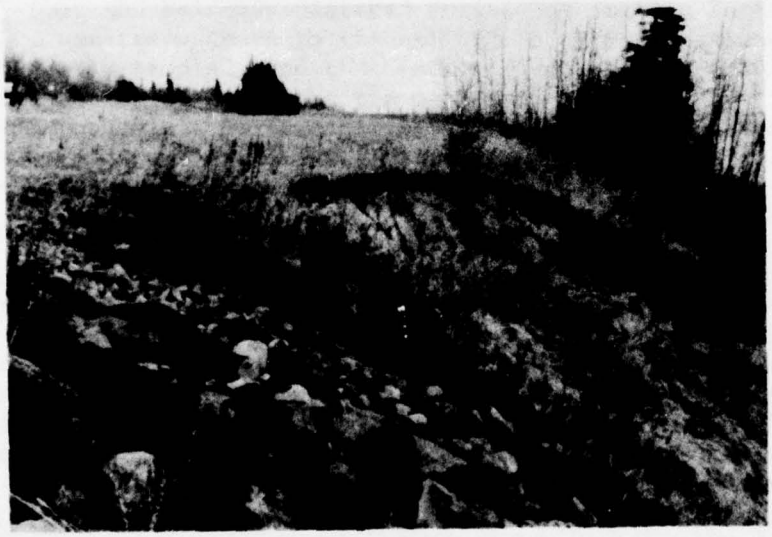


Figure B-10

APPENDIX D

STUDY DESIGN AND STATISTICAL ANALYSIS

The Great Lakes Shoreline Damage Survey in St. Louis County, began in November 1974, and is concerned with the damages sustained during the time period beginning Labor Day 1972 and extending through Labor Day 1974. Damage data was acquired via a systematic study design incorporating a mail-out self-administered assessment and personal interviewing. The same study was administered in ten other Great Lakes counties involved in the fiscal year 1975 pilot study.

A sampling frame was developed in the beginning of the study in St. Louis County. The sampling frame was based upon county property ownership records. A total of 878 individual parcels were identified, of which 345 were classified as residential and the remaining 533 as non-residential. The residential parcel owners each received self-administered damage assessments by mail following a systematic set of procedures utilizing reminder post cards and certified second mailings to initial non-respondents. A total of 231 usable assessments were returned, or a response of 67 percent.

The mail responses were sorted into two sub-groups or sub-populations in order to assist in the elimination of bias and to control for measurement error.[4] The two sub-populations were 1) respondents whose assessments were complete and usable or partially usable, or 2) non-respondents and respondents whose self-administered assessments were incomplete and not usable.

After completion of the mail-out and sorting, the respondents and non-respondents were identified and a random sample of 50 parcels were selected for follow-up personal interview. The random sample generated parcels from both sub-sets, respondents and non-respondents to the questionnaire. It was at this point that the self-administered assessment sorting became most important. The non-respondents to the self-administered assessments were identified, randomly sampled, and then interviewed in order to provide data from which to make inferences about the damage conditions experienced by the group of non-respondents. Statistical tests were then undertaken to determine if there were significant differences between the respondents and those included in the personal interviews.

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[4]With the usage of a mail-out self-administered assessment it is assumed that a certain percent of the people will not respond. In order to make inferences for this non-responding group, the bias of respondents vs. non-respondents must be taken into account and eliminated, if possible. Elimination of bias in this instance was afforded through the interviewing of non-respondents to the self-administered assessment. The interview data could then be compared with respondent data, and inferences made based on statistical testing procedures These same steps will also assist in the control for any measurement error that may prevail.

All non-residential parcel owners were contacted for personal interview appointments of which 27 interviews were completed, or a 65 percent response rate.[5] It should be emphasized that the occupants of non-residential parcels did not receive a mail-out self-administered assessment and were only subject to personal interviewing. Thus, projections could not be made for those non-residential owners refusing to participate in the interview.

Structured interviewing was emphasized throughout the interviewing phase to ensure consistency between responses and to control bias associated with the use of interview personnel. The interview instruments were furnished by U.S. Army Corps of Engineers and consisted of both flooding and erosion forms for the following land use classifications: residential, commercial/industrial, utility, transportation, and agriculture. Students having a geology background were employed from the University of Minnesota, Duluth to conduct the personal interviews and field reconnaissance.

The processing of information supplied by the various instruments was computerized for the residential properties and hand tabulated for non-residential properties.[6]

The Statistical Package for the Social Sciences (SPSS)[7] computer programming language was used for data processing. The system was adopted for the summary and analysis of the data. It performed many summary and analysis tasks with a minimum of effort. More importantly, comparison of cross-tabulations of variables from different records and alterations to record controls were accomplished quickly with the use of a minimum number of data entry or control cards. In short, the system proved to be an efficient aid in the compilation and analysis of residential data.

Data analysis was begun by comparing sub-population parameter values. This provided information needed for projecting estimates for the entire residential shoreline population. The three sub-populations identified for parameter testing are as follows: 1) respondents to the self-administered mail-out assessment, 2) respondents to the follow-up personal interview of respondents to self-administered assessment, and 3) respondents to the follow-up personal interview of non-respondents to the self-administered assessment. A total of 50 interviews were randomly selected from the

---

[5]Most non-residential parcel owners hold title to multiple parcels of land; as a result, a small number of non-residential interviews were required than that suggested by the total parcel numbers identified.

[6]Hand tabulations were employed because of the relatively small number of interview response forms.

[7]Statistical Package for the Social Sciences, Norman H. Niel, Dale H. Bent, and C. Hadlan Hull, Copyright 1970, by McGraw Hill, Inc.

groups of respondents and non-respondents. Of this total, 30 were completed with 28 of 38 returned by the second sub-population class and 2 of 12 from the third sub-population. The small number of responses obtained from the third sub-population prevent making meaningful statistical comparisons between non-respondents and respondents. During attempts to interview non-respondents it was generally found that property owners were unwilling to take the time to cooperate. In other instances parcel owners were "out of town or vacant landlords" and indicated they did not feel capable to address specific questions regarding damage conditions.

Statistical Analysis

Some accuracy in the statistical projections presented in this report is lost because the samples were drawn from non-normal populations. The presence of non-normality does not result in a sample mean being a biased estimator of the population mean. "It can be shown for example, that the average value of the sample mean taken over all possible samples of the same size is equal to the population mean regardless of the form of the population."[8] However, it does complicate the inferences that can be drawn from such sample means. The common properties of non-normality, skewness and kurtosis[9] increase the variance of the estimator of the sample variance, and therefore reduce the accuracy of results. Furthermore, the mean will frequently have a substantially different value compared to the median. In such cases, care must be exercised in using sample means in describing the population of interest.

The sample populations of the critical variables analyzed in this report were investigated to ascertain the degree of non-normality present. To accomplish this objective, the following steps were undertaken:

1. Histograms were drawn for the critical variables.
2. Skewness and kurtosis estimates were obtained from the statistical program employed in analyzing the data.
3. The significance level of these coefficients was assessed.
4. A log transformation was undertaken for each of the variables analyzed.
5. The skewness and kurtosis estimates were analyzed as to their statistical significance.

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[8] Elements of Statistical Inference, David B. Huntsburger, Allyn & Bacon Boston, Mass. 1967, p. 141.

[9] Statistical Methods, George W. Snedecor and William C. Cochran, The Iowa State University Press, Ames, Iowa, 1967, p. 89.

Figures 1,2 and 3 are histograms for three of the variables in this analysis. These histograms were chosen for representation because they typify the types of sample population that were encountered. It was observed that the histograms indicated that the populations may conform more closely to a log normal distribution than to a normal distribution.

Values for skewness and kurtosis were obtained for six variables and for Reaches 3 and 4 as presented in the table. It was found that all the variables in both reaches had a significant level of skewness, and all but one were significant at the 1 percent or better significance level and the remaining one was significant at the 5 percent level. The kurtosis coefficient was somewhat less consistent. Nine of the twelve kurtosis readings showed significance at the 1 percent level, two of the twelve at the 5 percent level and one reading showed no significant kurtosis.

Log transformation of the data did reduce some of the distortion present. After the transformation, only three of the twelve readings had a significant level of skewness. The kurtosis factor, however, worsened. After transformation, all of the 12 readings had significant levels of kurtosis at the 1 percent significance level.

It can be concluded that a log transformation does not eliminate the distortion problems inherent in the sampling distributions. Whether or not the projections could be improved through this type of transformation, is not obvious from the results that were obtained. Further statistical analysis is necessary to make this determination.

The data from which the projections were made is available if it is decided that additional statistical refinements are warranted at a later date. The value of such refinements is dependent on the overall accuracy of the testing process that was undertaken. The total error of this process is comprised of a sampling component and a statistical component. If it is determined that the statistical component is large in relation to the sampling component, then analysis through more advanced statistical techniques may be warranted.

It should be noted that other parametric and non-parametric tests were undertaken to compare the means and medians of data subsets of the variables tested. These statistical procedures are presented in Appendix V, Shoreline Damage Survey: An Appraisal with Recommendations.

STATISTICAL PROPERTIES OF SELECTED VARIABLES

Variables	Sample Size	REGULAR DATA Skewness	REGULAR DATA Kurtosis	LOG TRANSFORMED DATA Skewness	LOG TRANSFORMED DATA Kurtosis
Reach 3(71)					
Erosion Damage	25	1,444**	1,987**-	.088	-1.058**-
Flood Damage	33	1,942**	3,191	.008	- .991**-
Protective Action					
Materials	26	.594	- .972	- .709	.602**-
Labor	32	2.635**	7.809**+	.043	- .621**-
Bluff Volume Lost	19	1.825**	2.198*-	.180	- .501**-
Beach Area Lost	13	2.351**	4.077*+	1.409**	.825**-
Reach 4 (157)					
Erosion Damage	50	2.728**	7.895**+	.082	- .647**-
Flood Damage	28	.921*	- .639**-	- .471	- .845**-
Protective Action					
Materials	22	2.643**	7.065**+	- .017	- .950**-
Labor	20	1.357**	1.538**-	- .285	- 1.278**-
Bluff Volume Lost	70	6.605**	45.857**+	1.125**	1.719**-
Beach Area Lost	80	6.614**	47.611**+	1.029**	1.281**-

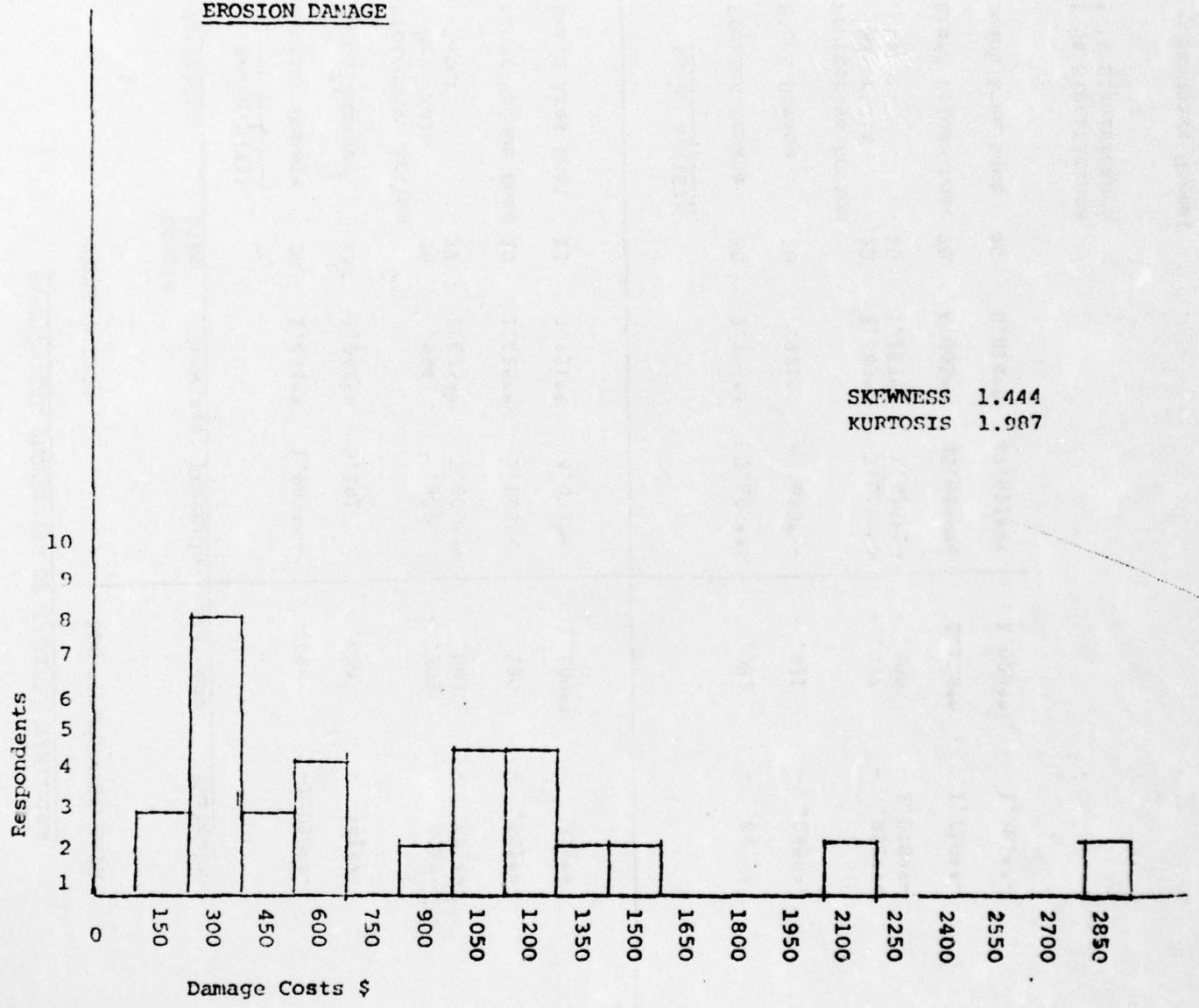
* 5% Significance
** 1% Significance

0 - Skewness Normal

3 - Kurtosis Normal

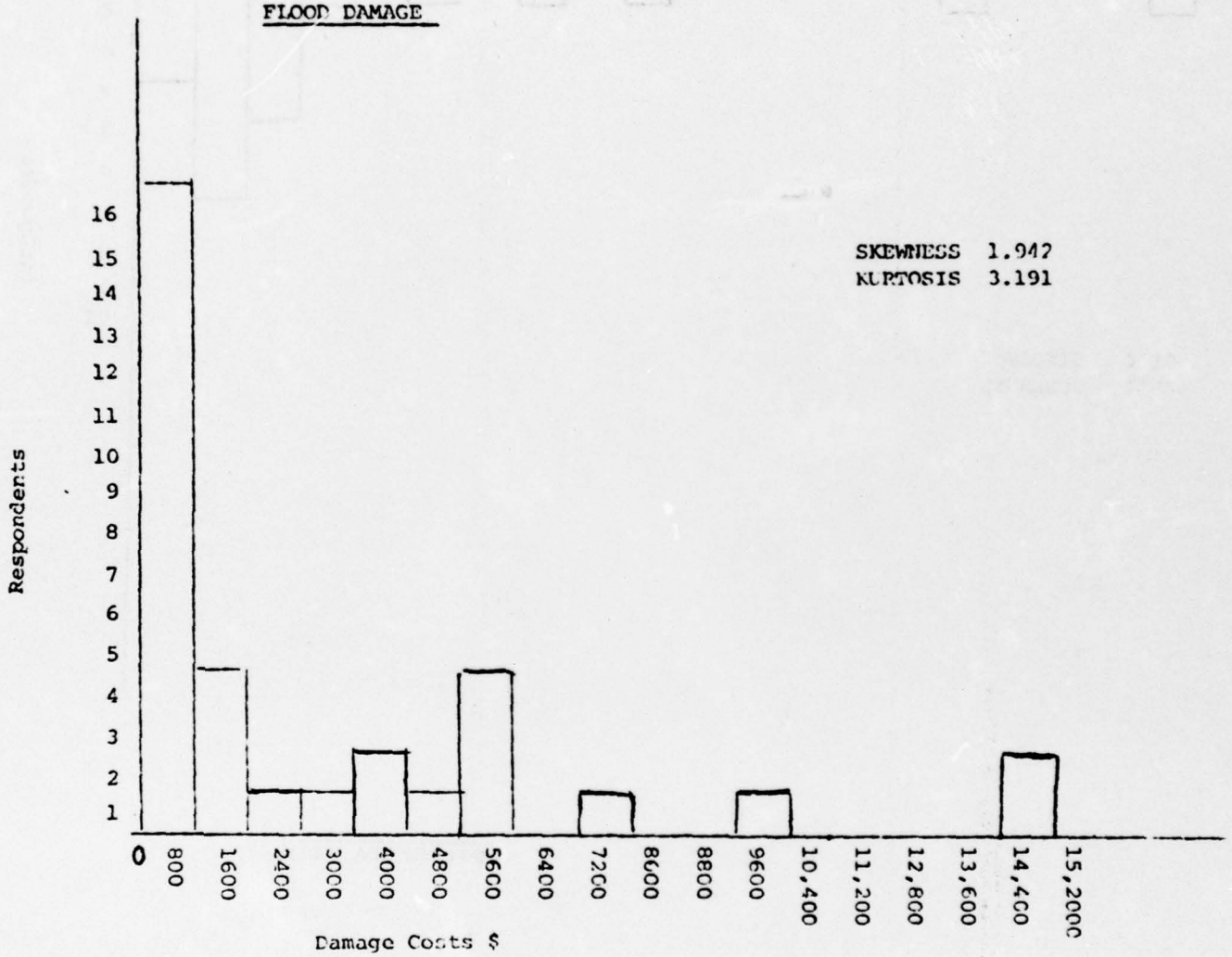
REACH 3

EROSION DAMAGE



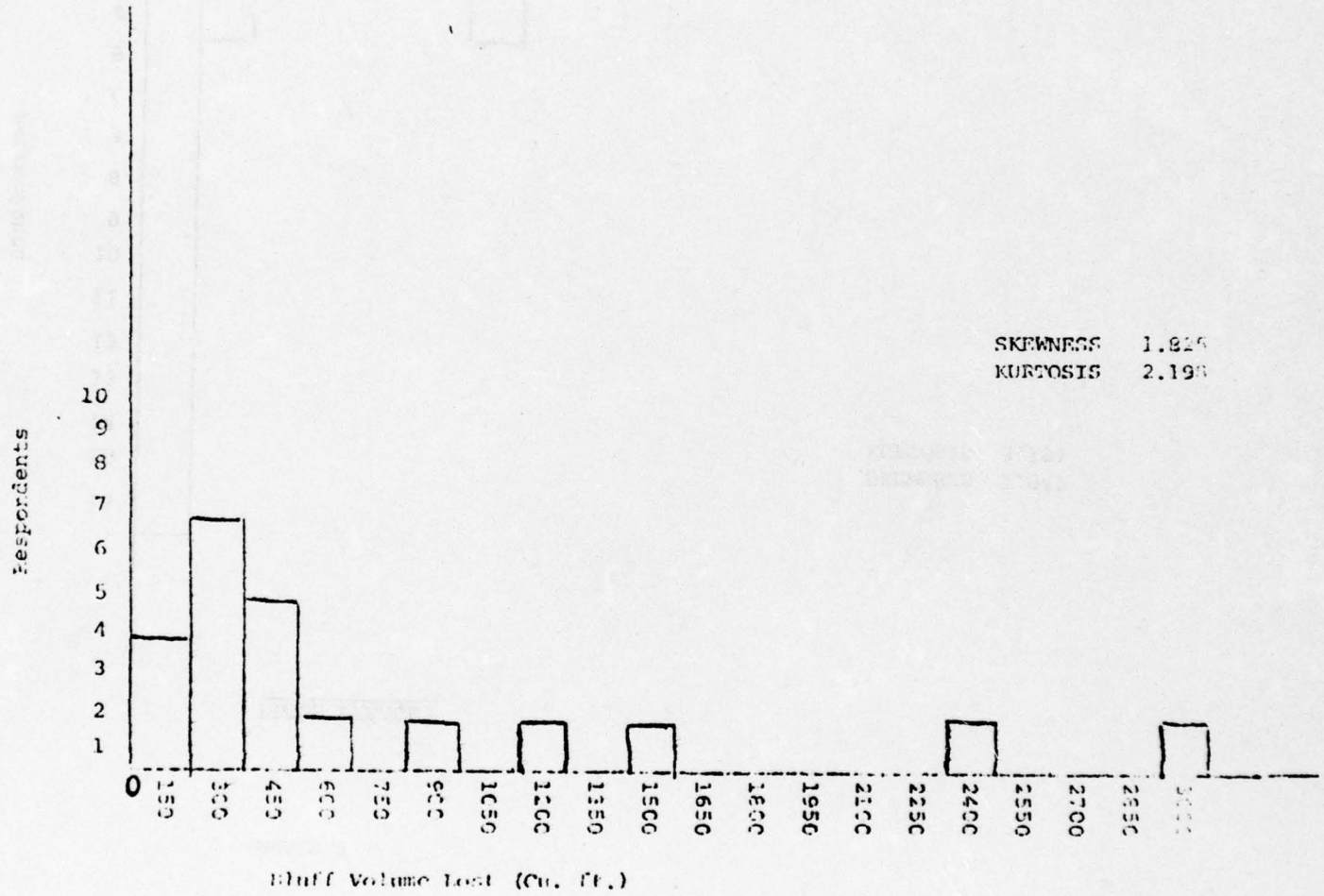
REACH 3

FLOOD DAMAGE



REACH 3

BLUFF VOLUME LOST



GLOSSARY

1. Armor the toe of the bluff: a general term for shoreline protection along the low erodible portions of an exposed coastline.

2. Artificial fill area: an area of coastline artificially produced by the dumping of dredged or excavated materials.

3. Bay: a wide indentation in the coastline of any body of water.

4. Baymouth bar: a depositional bar parallel to a shoreline. Its crest is above the waterline, affording protection from wave action for the embayed side of this feature.

5. Bluff: a sometimes steeply graded bank or cliff.

6. Breakwater: a protective structure either natural or man-made which serves as a barrier to the horizontal movements of waves. These are often found as protective devices on harbor perimeters, waterfronts, or at the exposed portions of canal entrances.

7. Commercial Activities: retailing, wholesaling or marketing of professional, business or personal services.

8. Dissipation of wave energy off-shore: a reduction in the amount of wave energy directed at the shore area. This is achieved through the construction of protective jetties, groins, breakwaters, etc.

9. Dunes: heaps or rolling mounds of loose, wind-blown materials (sand for the purposes of this study).

10. Entrainment of shoreline materials: a condition in which beach materials are drawn in and transported by the flow of water along the shoreline.

11. Erosion: the gradual wearing away of earth materials by natural conditions.

12. Fetch: In wave forecasting, the horizontal distance (in the direction of the wind) over which the wind blows.

13. Groin: a shore protective measure designed to trap littoral drift or to reduce shoreline erosion, usually built perpendicular to the shoreline.

14. Harbor: a sheltered section of coastline which may be used as a vessel refuge.

15. Jetty: a coastal structure designed to prevent channel deposition or shoaling, while affording protection to watercraft at the same time.

16. Littoral: at, near, or adjacent to the coast of Lake Superior. For the purposes of this study, within 200 feet of the lake.

17. Low-water datum: Lake Superior at 600.0 feet above sea level as set by the IGLD in 1955.

18. Public Lands: shore properties owned by the Federal, State, or local governments, or those owned by quasi-public agencies or organizations who do not restrict citizen usage of that property.

19. Residential: an area where single or multi-family dwellings are adjacent to the shoreline.

20. Revetment: a shore protective structure having a facing of stone, mortared block, or concrete. Such a device is designed to impede the erosion of a bluff, dune, or other coastal features due to wave attack, littoral drift, etc.

21. Riparian rights: the legal mechanism which guarantees the owner of lake shore property certain rights relating to access and usage of said property.

22. Rip-rap: a layer of protective materials, usually of uniform size and distribution which are placed as a lining upon a shoreline in order to prevent erosion. Also the material so used.

23. Seiche: the periodic oscillation of water levels on Lake Superior due to physical processes. A kind of tidal wave action. The term applies to harbors, bays, and the entire lake basin itself.

24. Shore: the strip of coast immediate to the water's edge. Usually of consolidated materials; unconsolidated shorelines are referred to as beaches.

25. Shoreline protection: engineering or structural features built along the littoral zone which relieves erosion or flooding.

26. Slope: degree of incline, with specific reference in this damage assessment project to the variance of a shore or beach from the horizontal.

27. Topography: the inherent characteristics of a landscape, its nature, geomorphology, and the general lay of the land.

28. Wetlands: coastal areas of low relief, possessing inadequate drainage and usually being in an undeveloped state.

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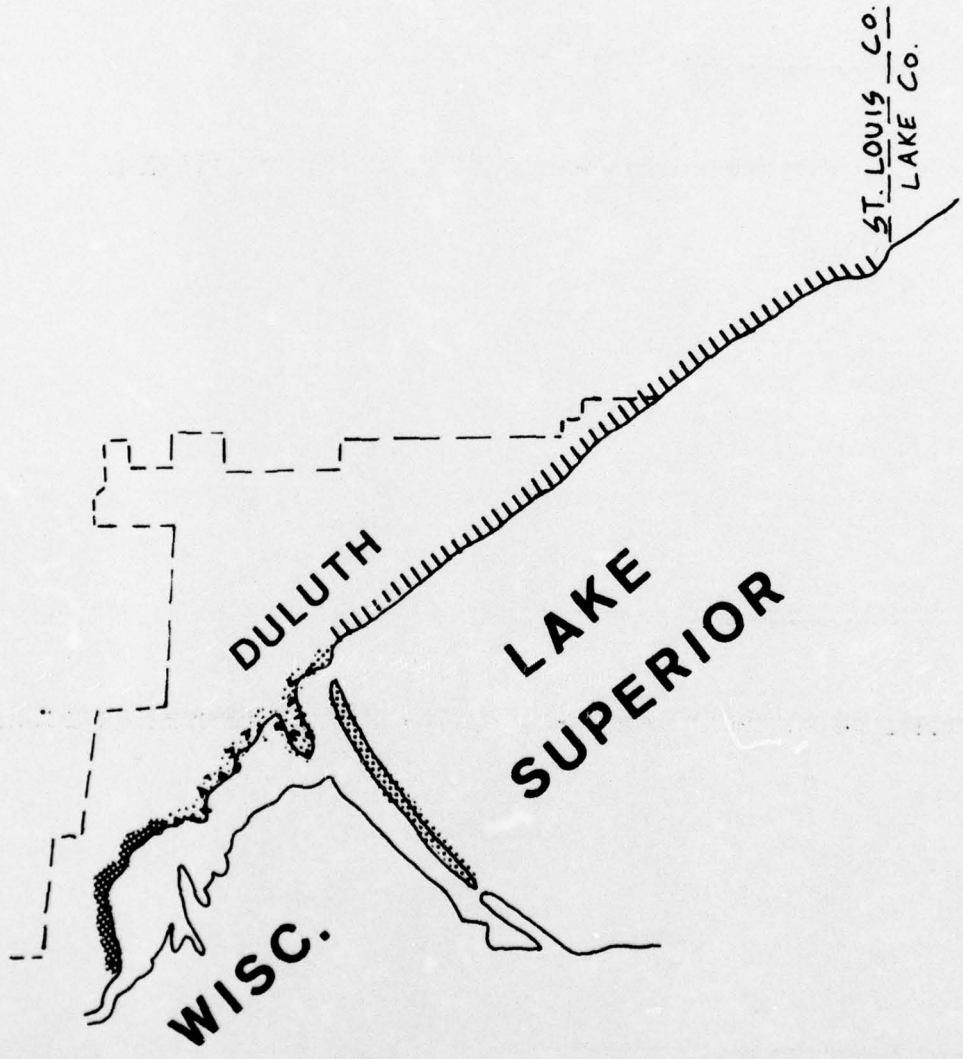
THE FOUR STUDY AREA REACHES

ST. LOUIS COUNTY
GREAT LAKES
SHORELINE DAMAGE SURVEY



REACH NO. 1
REACH NO. 2
REACH NO. 3
REACH NO. 4

SCALE
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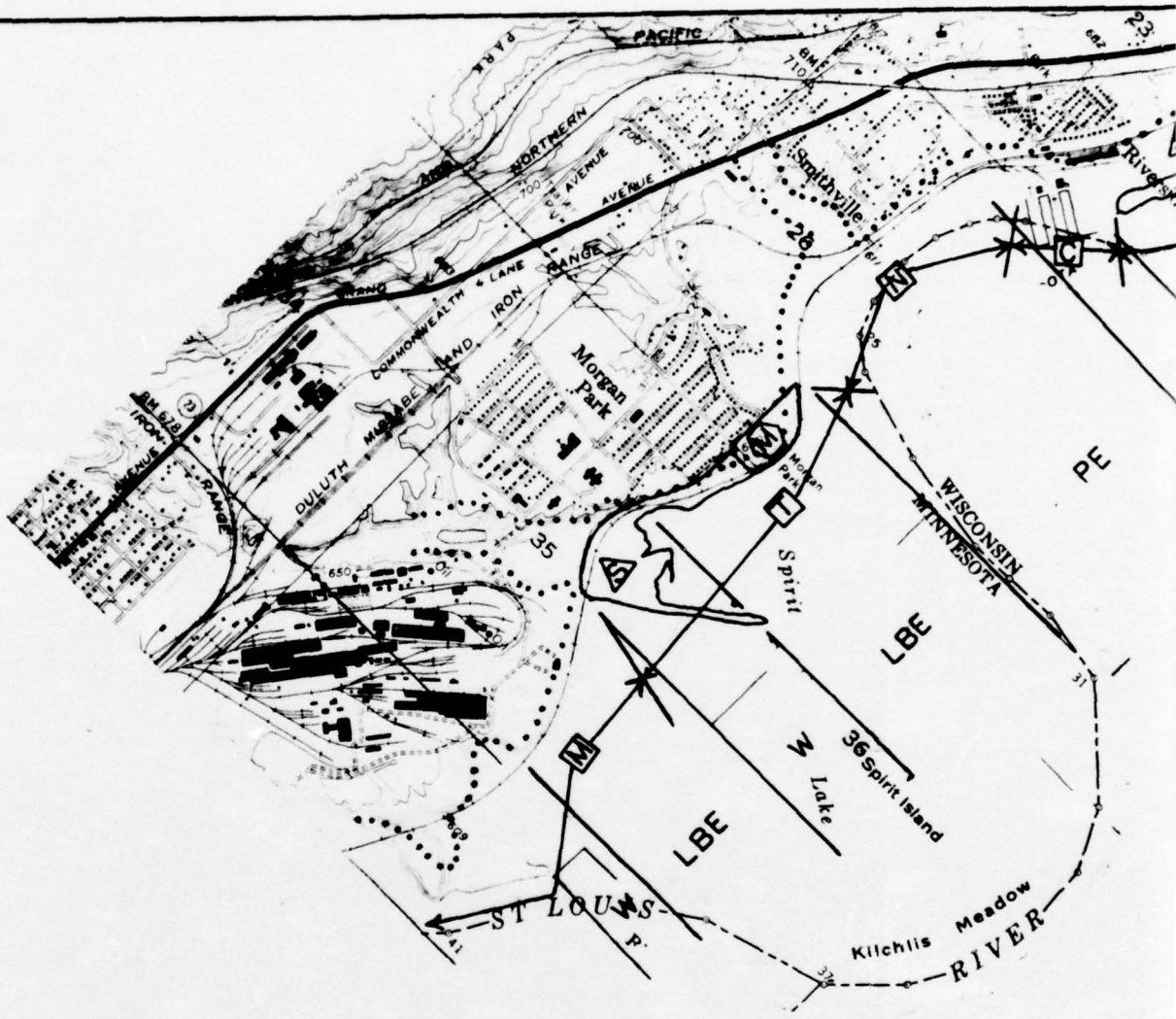
PLATE 1



LEGEND

(1) SHOREFORMS

A	Artificial Fill Area
HBE	Erodible High Bluff-30 ft. or higher
HBN	Non-Erodible High Bluff-30 ft. or higher
LBE	Erodible Low Bluff-less than 30 ft.
LBN	Non-Erodible Low Bluff-less than 30 ft.
HD	High Sand Dune-30 ft. or higher
LD	Low Sand Dune-less than 30 ft.
PE	Erodible Low Plain
PN	Non-Erodible Low Plain
W	Wetlands

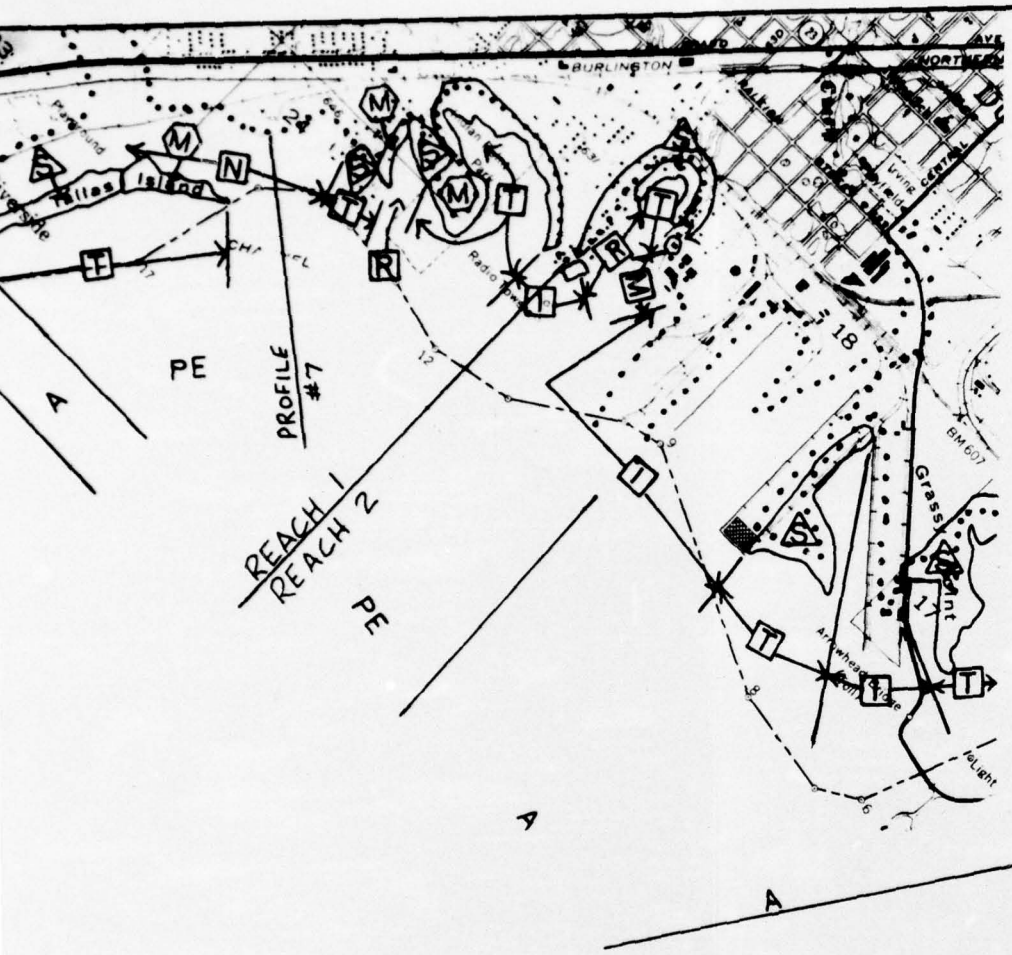
(2) SHORELAND USE

- [R] Residential
- [C] Commercial
- [I] Industrial
- [M] Manufacturing
- [U] Utility
- [N] Non-Developed
- [T] Tax Exempt

(3) SHORELAND OWNE

- [F] Federal
- [S] State
- (C) County
- (M) Municipal

Private



NERSHIP

④ SHORELINE PROTECTION STRUCTURES -------

⑤ FLOOD PLAIN ••••••

SCALE

0 feet 2000

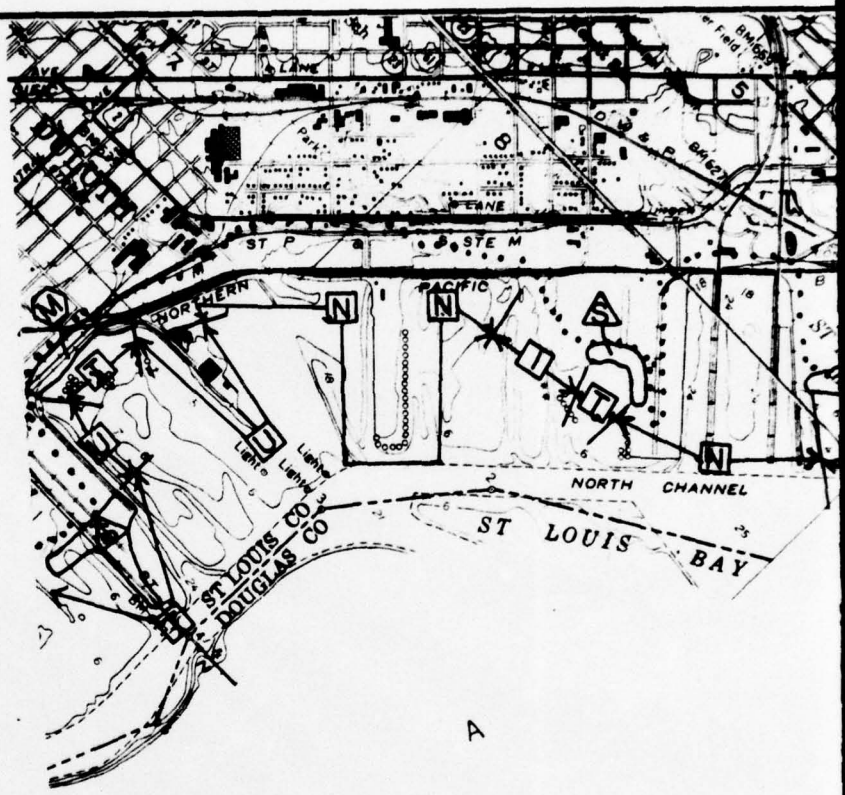
DEPARTMENT OF THE ARMY
NORTH CENTRAL DIVISION, CORPS OF ENGINEERS
CHICAGO, ILLINOIS

GREAT LAKES SHORELINE DAMAGE SURVEY

ST. LOUIS COUNTY, MINNESOTA
NOVEMBER, 1975

PLATE 2

2



LEGEND

(1) SHOREFORMS

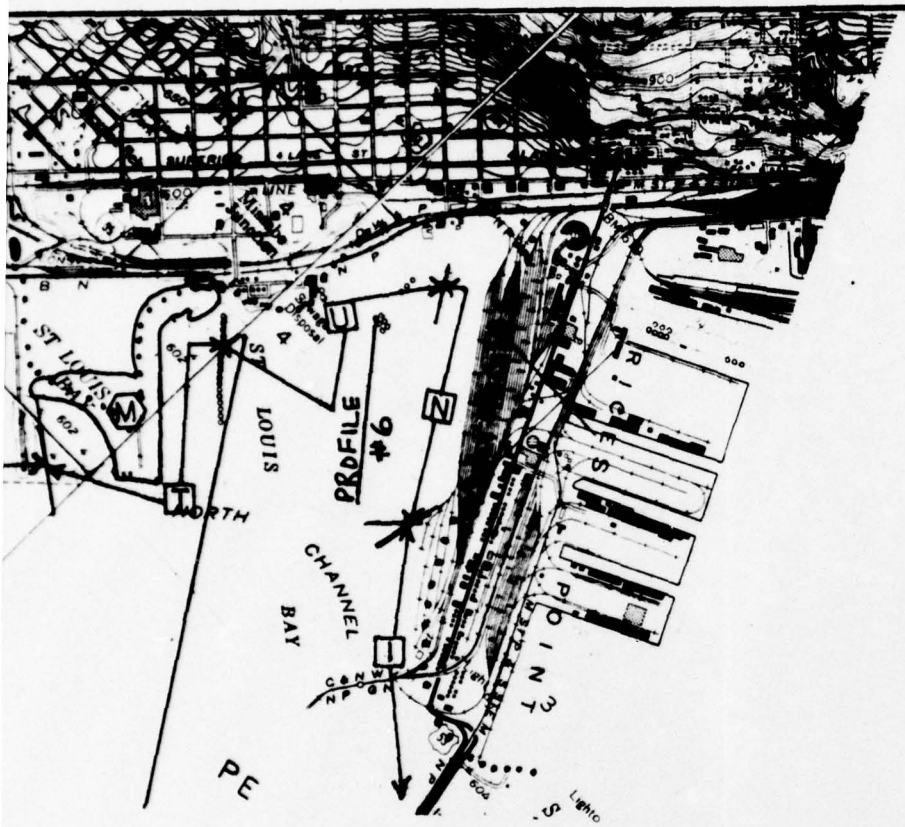
A	Artificial Fill Area
HBE	Erodible High Bluff-30 ft. or higher
HBN	Non-Erodible High Bluff-30 ft. or higher
LBE	Erodible Low Bluff-less than 30 ft.
LBN	Non-Erodible Low Bluff-less than 30 ft.
HD	High Sand Dune-30 ft. or higher
LD	Low Sand Dune-less than 30 ft.
PE	Erodible Low Plain
PN	Non-Erodible Low Plain
W	Wetlands

(2) SHORELAND USE

- [R] Residential
- [C] Commercial
- [I] Industrial
- [M] Manufacturing
- [U] Utility
- [N] Non-Developed
- [T] Tax Exempt

(3) SHORELAND OWNERS

- [F] Federal
- [S] State
- [C] County
- [M] Municipal
- Private



NERSHIP

④ SHORELINE PROTECTION STRUCTURES ------

⑤ FLOOD PLAIN ......

SCALE

0 feet 2000

DEPARTMENT OF THE ARMY
NORTH CENTRAL DIVISION, CORPS OF ENGINEERS
CHICAGO, ILLINOIS

GREAT LAKES SHORELINE DAMAGE SURVEY

ST. LOUIS COUNTY, MINNESOTA
NOVEMBER, 1975

PLATE 3

LEGEND

(1) SHOREFORMS

A	Artificial Fill Area
HBE	Erodible High Bluff-30 ft. or higher
HBN	Non-Erodible High Bluff-30 ft. or higher
LBE	Erodible Low Bluff-less than 30 ft.
LBN	Non-Erodible Low Bluff-less than 30 ft.
HD	High Sand Dune-30 ft. or higher
LD	Low Sand Dune-less than 30 ft.
PE	Erodible Low Plain
PN	Non-Erodible Low Plain
W	Wetlands

(2) SHORELAND USE

- [R] Residential
- [C] Commercial
- [I] Industrial
- [M] Manufacturing
- [U] Utility
- [N] Non-Developed
- [T] Tax Exempt

(3) SHORELAND OWNER

- [F] Federal
- [S] State
- (C) County
- (M) Municipal
- Private

A A A

D OWNERSHIP

(4) SHORELINE PROTECTION STRUCTURES ------

(5) FLOOD PLAIN ·····

SCALE

0 feet 500

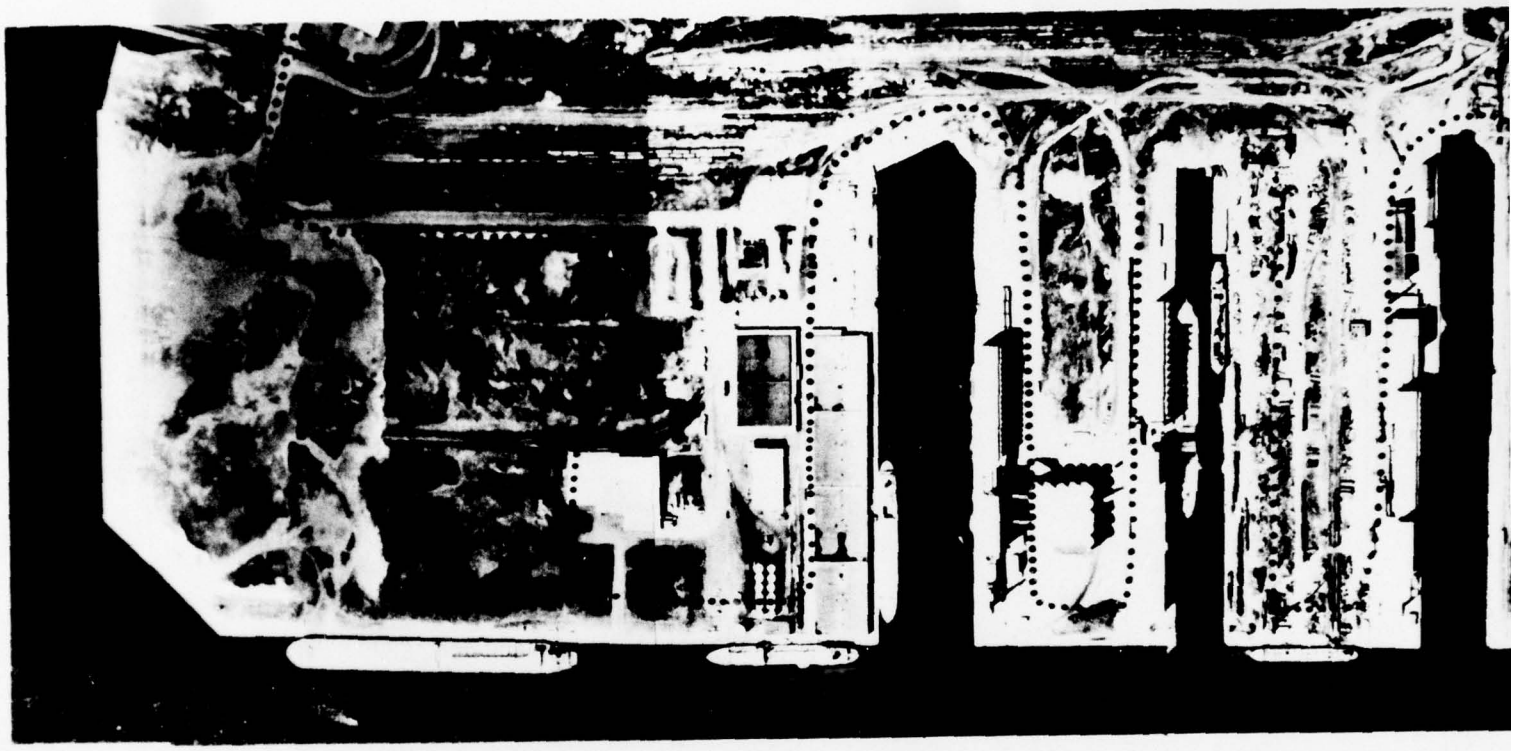
DEPARTMENT OF THE ARMY
NORTH CENTRAL DIVISION, CORPS OF ENGINEERS
CHICAGO, ILLINOIS

GREAT LAKES SHORELINE DAMAGE SURVEY

ST. LOUIS COUNTY, MINNESOTA
NOVEMBER, 1975

PLATE 4

2



A A

LEGEND

(1) SHOREFORMS

A	Artificial Fill Area
HBE	Erodible High Bluff-30 ft. or higher
HBN	Non-Erodible High Bluff-30 ft. or higher
LBE	Erodible Low Bluff-less than 30 ft.
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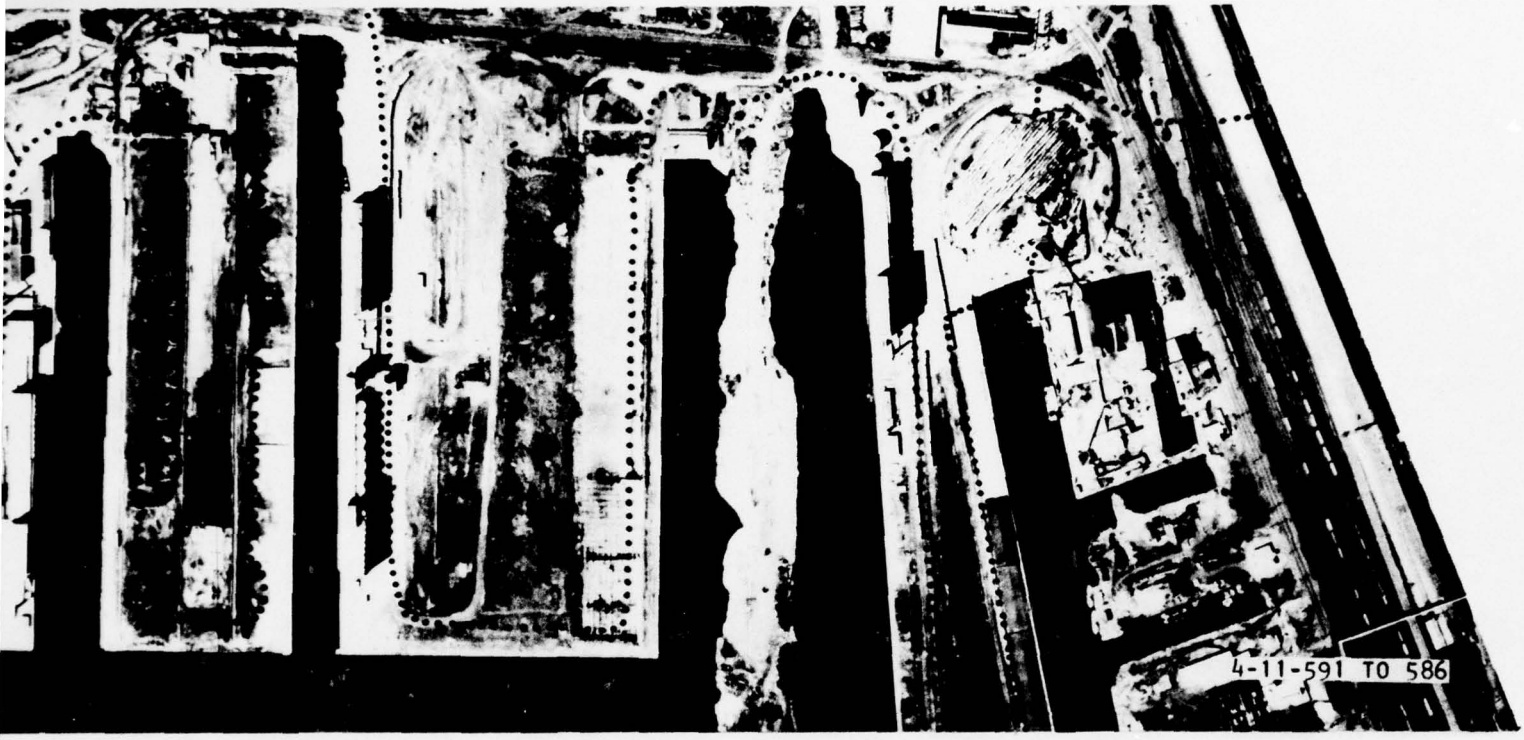
HD	High Sand Dune-30 ft. or higher
LD	Low Sand Dune-less than 30 ft.
PE	Erodible Low Plain
PN	Non-Erodible Low Plain
W	Wetlands

(2) SHORELAND USE

- [R] Residential
- [C] Commercial
- [I] Industrial
- [M] Manufacturing
- [U] Utility
- [N] Non-Developed
- [T] Tax Exempt

(3) SHORELAND OWN

- [F] Federal
- [S] State
- (C) County
- ⟨M⟩ Municipal
- Private



A A

AND OWNERSHIP

④ SHORELINE PROTECTION STRUCTURES - - - - - -

⑤ FLOOD PLAIN . . . . . .

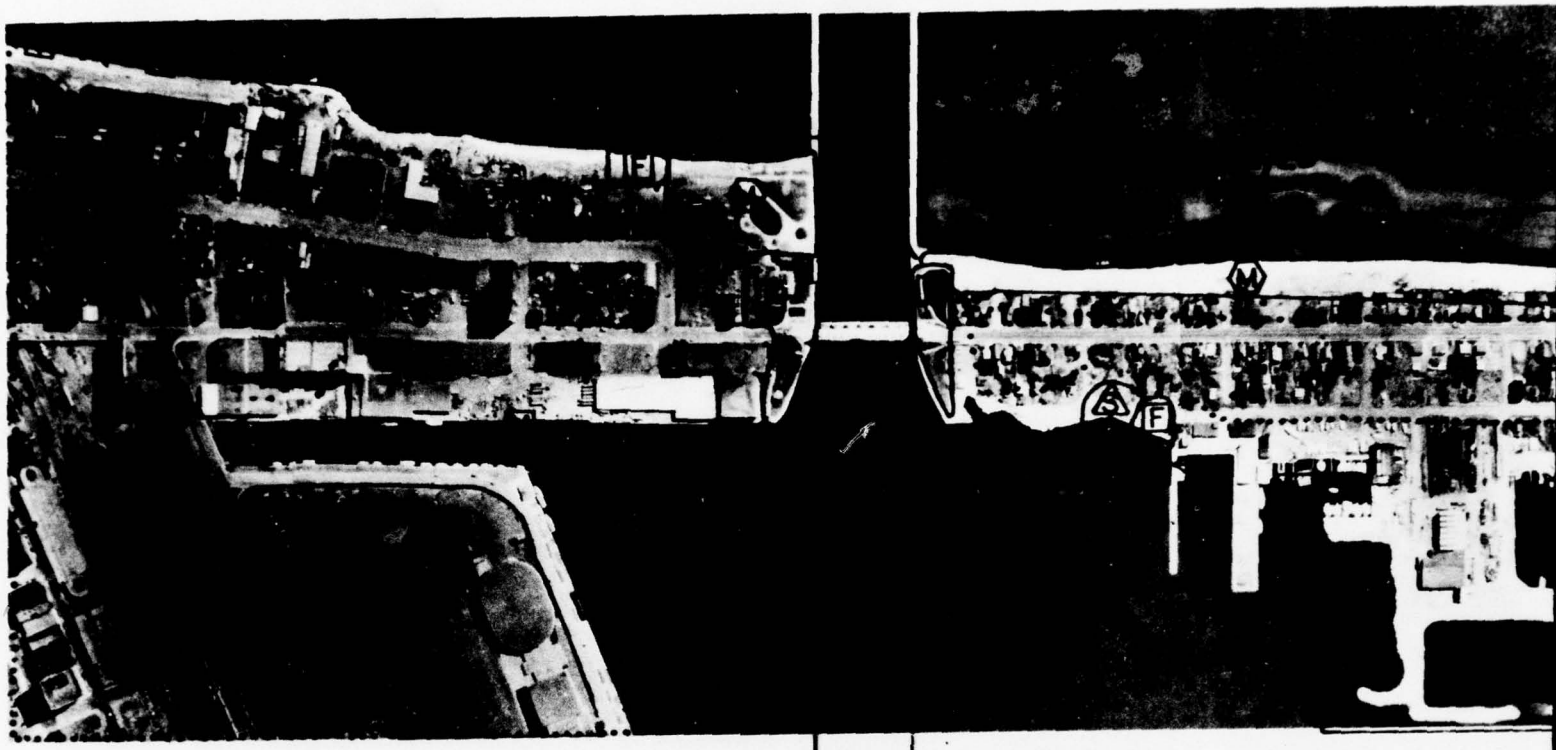
SCALE
0 feet 500

DEPARTMENT OF THE ARMY
NORTH CENTRAL DIVISION, CORPS OF ENGINEERS
CHICAGO, ILLINOIS

GREAT LAKES SHORELINE DAMAGE SURVEY

ST. LOUIS COUNTY, MINNESOTA
NOVEMBER, 1975

PLATE 5



A

LEGEND

(1) SHOREFORMS

A	Artificial Fill Area
HBE	Erodible High Bluff-30 ft. or higher
HBN	Non-Erodible High Bluff-30 ft. or higher
LBE	Erodible Low Bluff-less than 30 ft.
LBN	Non-Erodible Low Bluff-less than 30 ft.
HD	High Sand Dune-30 ft. or higher
LD	Low Sand Dune-less than 30 ft.
PE	Erodible Low Plain
PN	Non-Erodible Low Plain
W	Wetlands

(2) SHORELAND USE

- [R] Residential
- [C] Commercial
- [I] Industrial
- [M] Manufacturing
- [U] Utility
- [N] Non-Developed
- [T] Tax Exempt

(3) SHORELAND OWNERS

- [F] Federal
- [S] State
- (C) County
- ⟨M⟩ Municipal
- Private

A ABBUTTING WITH LD

FILL AND REVETMENTS

ND OWNERSHIP

(4) SHORELINE PROTECTION STRUCTURES - - - - - -

(5) FLOOD PLAIN . . . . . .

SCALE

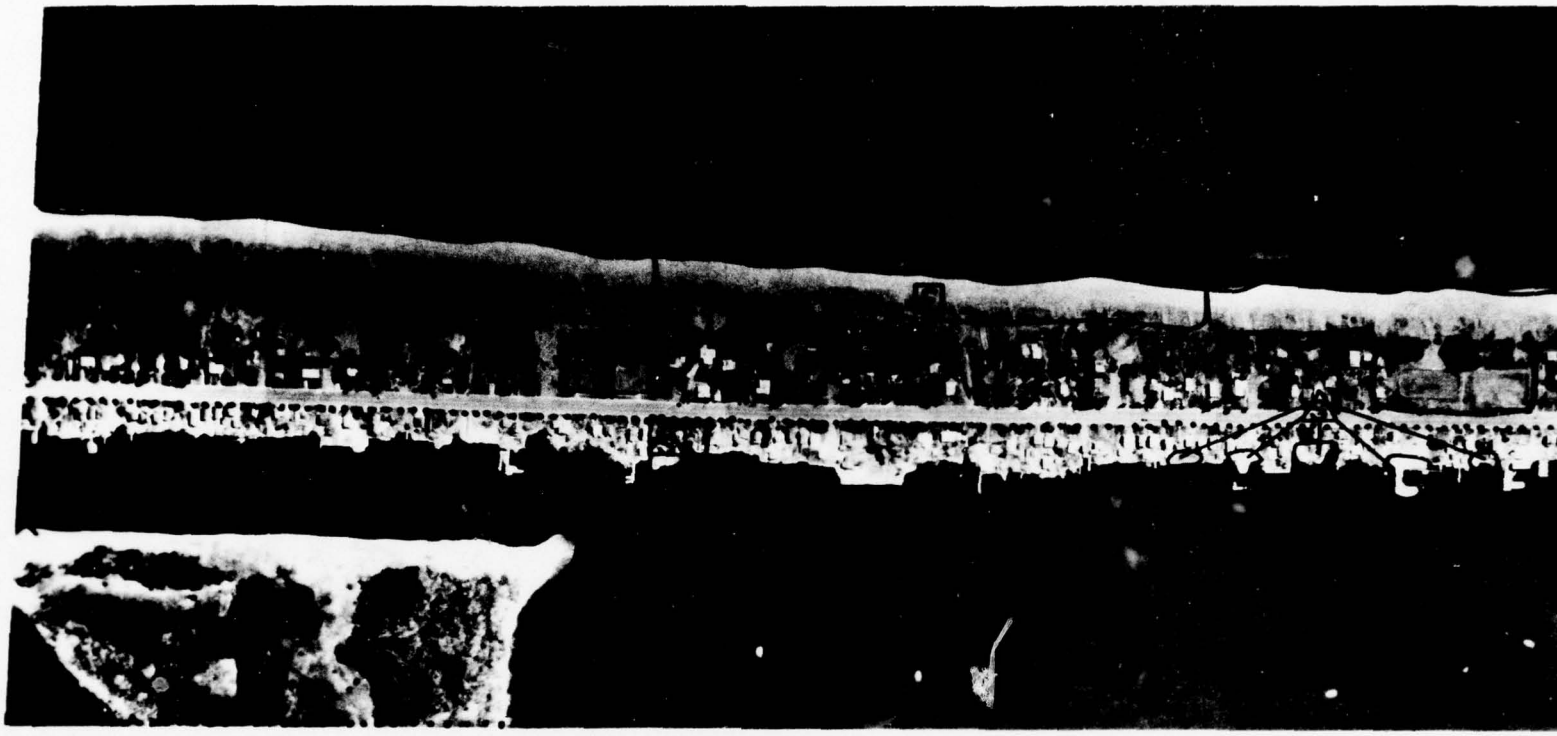
0 feet 500

DEPARTMENT OF THE ARMY
NORTH CENTRAL DIVISION, CORPS OF ENGINEERS
CHICAGO, ILLINOIS

GREAT LAKES SHORELINE DAMAGE SURVE

ST. LOUIS COUNTY, MINNESOTA
NOVEMBER, 1975

PLATE 2



LEGEND

(1) SHOREFORMS

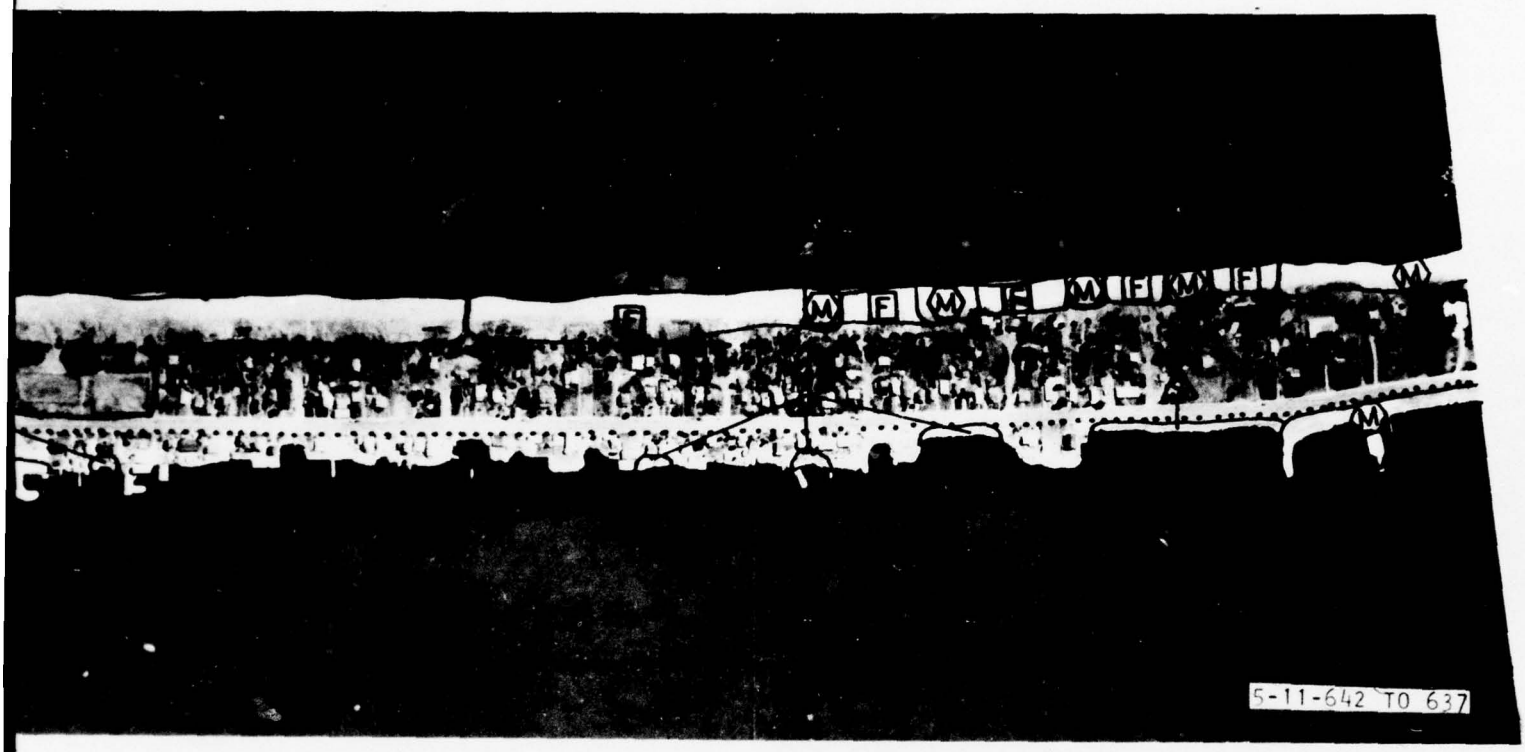
A	Artificial Fill Area
HBE	Erodible High Bluff-30 ft. or higher
HBN	Non-Erodible High Bluff-30 ft. or higher
LBE	Erodible Low Bluff-less than 30 ft.
LBN	Non-Erodible Low Bluff-less than 30 ft.
HD	High Sand Dune-30 ft. or higher
LD	Low Sand Dune-less than 30 ft.
PE	Erodible Low Plain
PN	Non-Erodible Low Plain
W	Wetlands

(2) SHORELAND USE

- [R] Residential
- [C] Commercial
- [I] Industrial
- [M] Manufacturing
- [U] Utility
- [N] Non-Developed
- [T] Tax Exempt

(3) SHORELAND OWNERSH

- [F] Federal
- [S] State
- (C) County
- (M) Municipal
- Private



D OWNERSHIP

④ SHORELINE PROTECTION STRUCTURES - - - - - -

⑤ FLOOD PLAIN . . . . . .

SCALE
0 feet 500

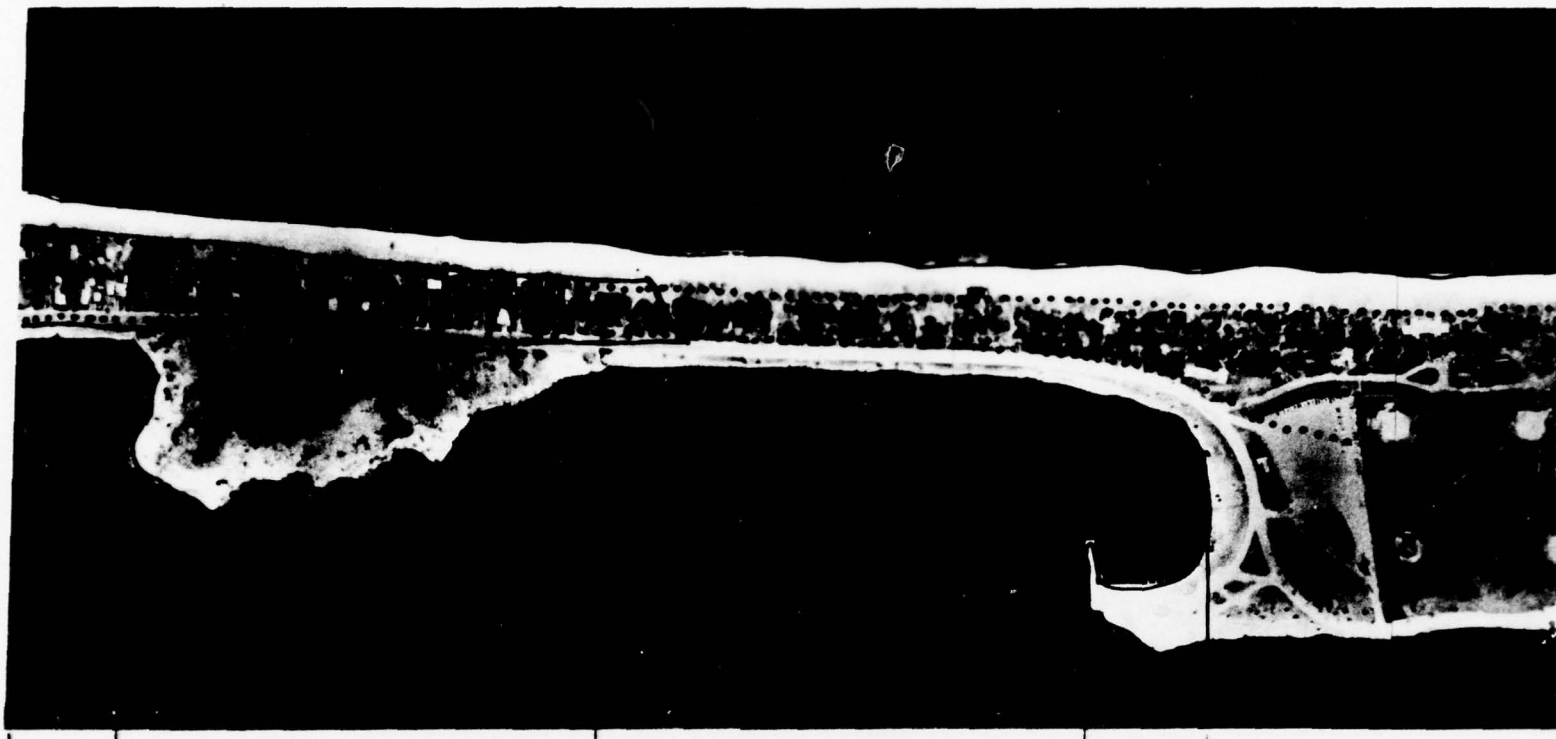
DEPARTMENT OF THE ARMY
NORTH CENTRAL DIVISION, CORPS OF ENGINEERS
CHICAGO, ILLINOIS

GREAT LAKES SHORELINE DAMAGE SURVEY

ST. LOUIS COUNTY, MINNESOTA
NOVEMBER, 1975

2

PLATE 7



LEGEND

(1) SHOREFORMS

A	Artificial Fill Area
HBE	Erodible High Bluff-30 ft. or higher
HBN	Non-Erodible High Bluff-30 ft. or higher
LBE	Erodible Low Bluff-less than 30 ft.
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- [C] Commercial
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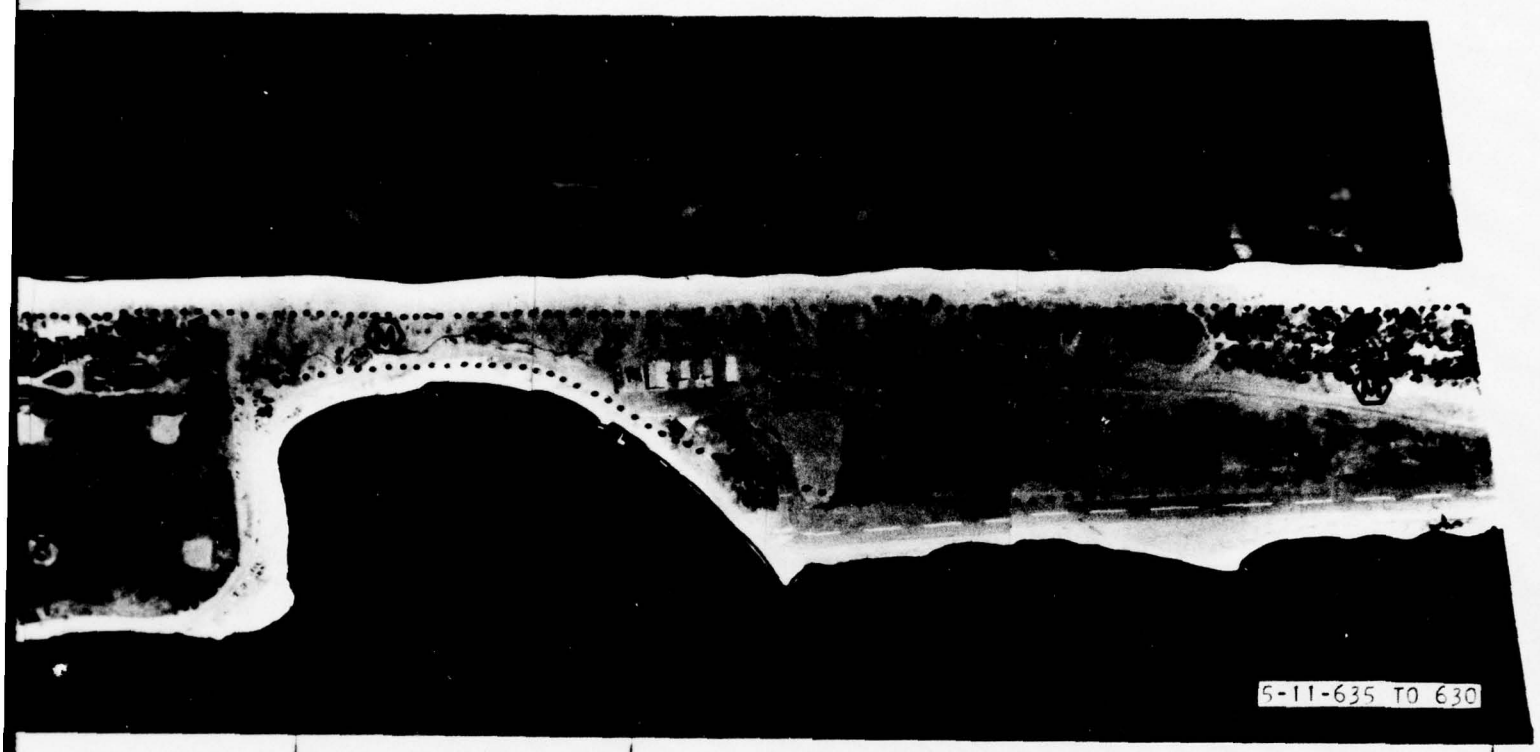
- (C) County
- (M) Municipal
- Private



A | LD | A REINFORCING NATURAL LD

ND OWNERSHIP

④ SHORELINE PROTECTION STRUCTURES - - - - - -

⑤ FLOOD PLAIN . . . . . .

SCALE
0 feet 500

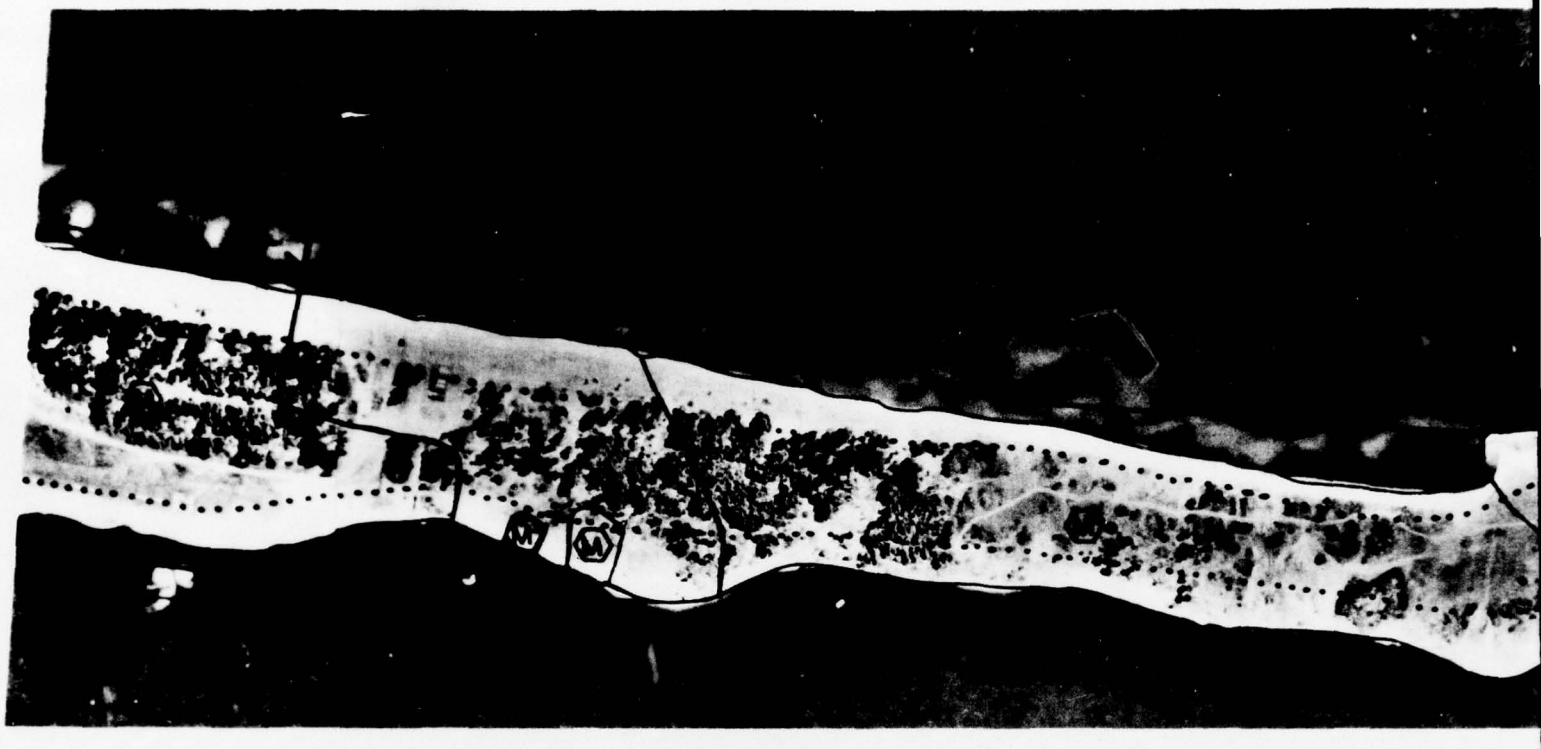
DEPARTMENT OF THE ARMY
NORTH CENTRAL DIVISION, CORPS OF ENGINEERS
CHICAGO, ILLINOIS

GREAT LAKES SHORELINE DAMAGE SURVE

ST. LOUIS COUNTY, MINNESOTA
NOVEMBER, 1975

PLATE 8

2



LEGEND

(1) SHOREFORMS

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HBE	Erodible High Bluff-30 ft. or higher
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- [C] Commercial
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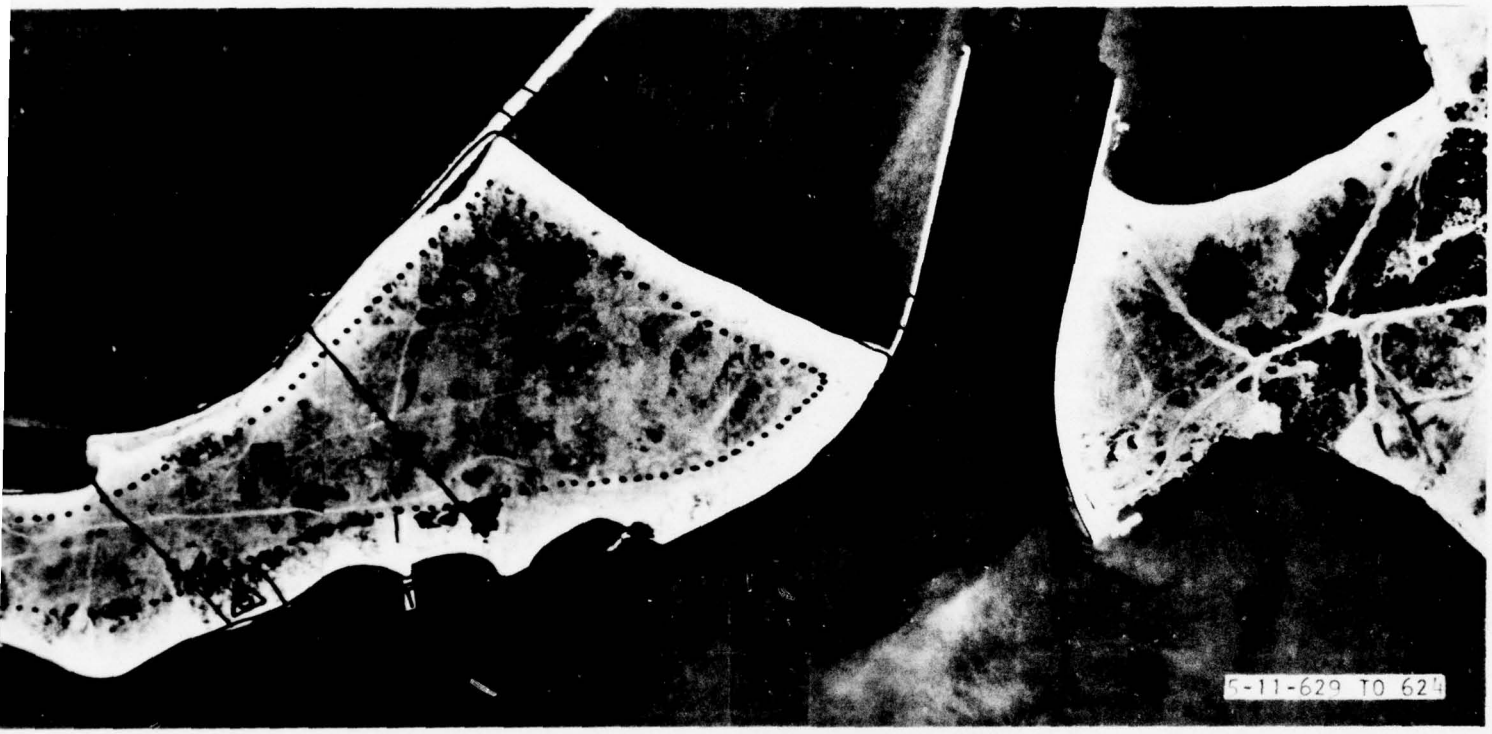
- [T] Tax Exempt

(3) SHORELAND OWNERS

- [F] Federal
- [S] State
- (C) County
- ⟨M⟩ Municipal
- Private



D OWNERSHIP

④ SHORELINE PROTECTION STRUCTURES - - - - - -

⑤ FLOOD PLAIN · · · · · ·

SCALE

0 feet 500

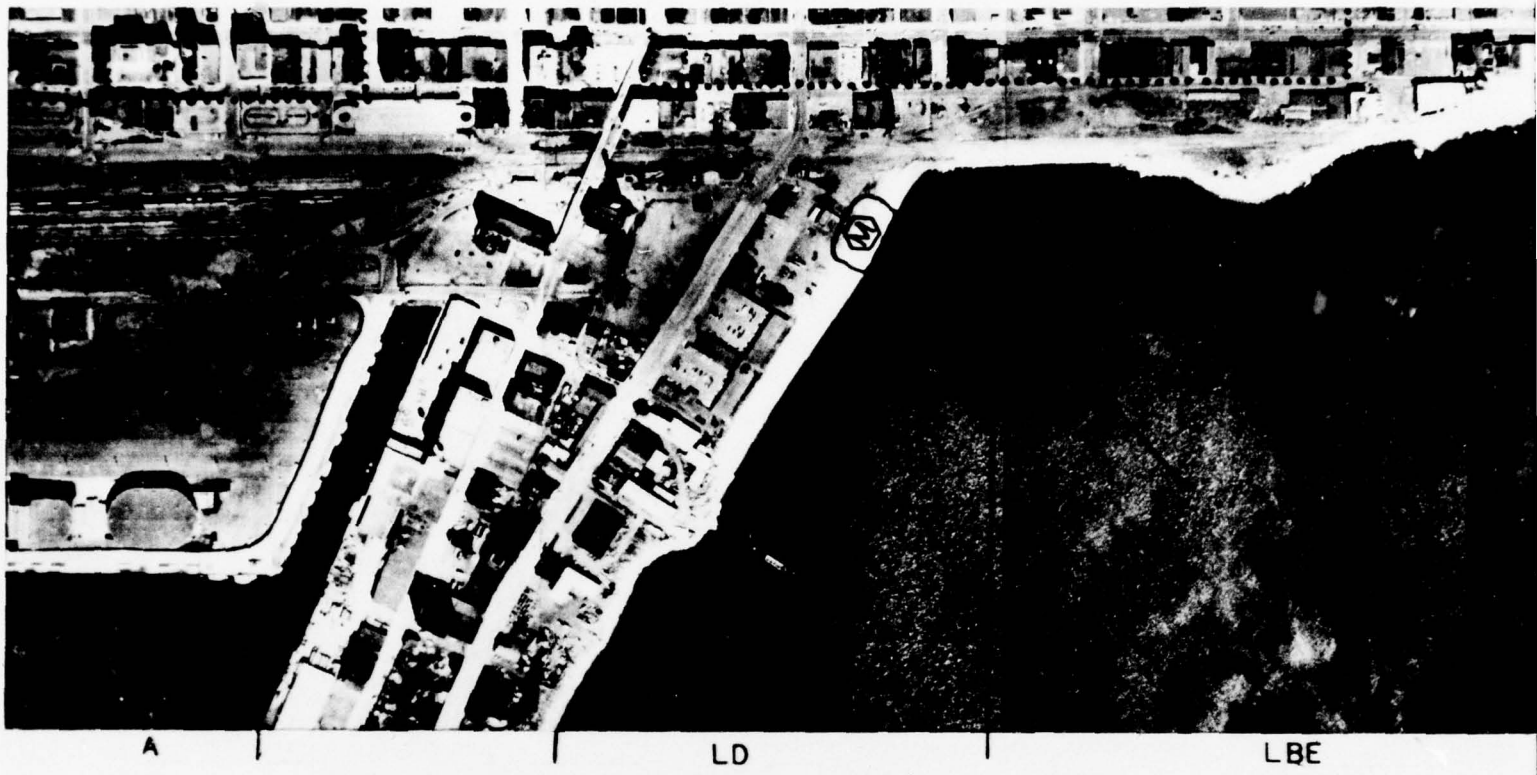
DEPARTMENT OF THE ARMY
NORTH CENTRAL DIVISION, CORPS OF ENGINEERS
CHICAGO, ILLINOIS

GREAT LAKES SHORELINE DAMAGE SURVEY

ST. LOUIS COUNTY, MINNESOTA
NOVEMBER, 1975

2

PLATE 9



LEGEND

(1) SHOREFORMS

A	Artificial Fill Area
HBE	Erodible High Bluff-30 ft. or higher
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(2) SHORELAND USE

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- [T] Tax Exempt

(3) SHORELAND OWNERS

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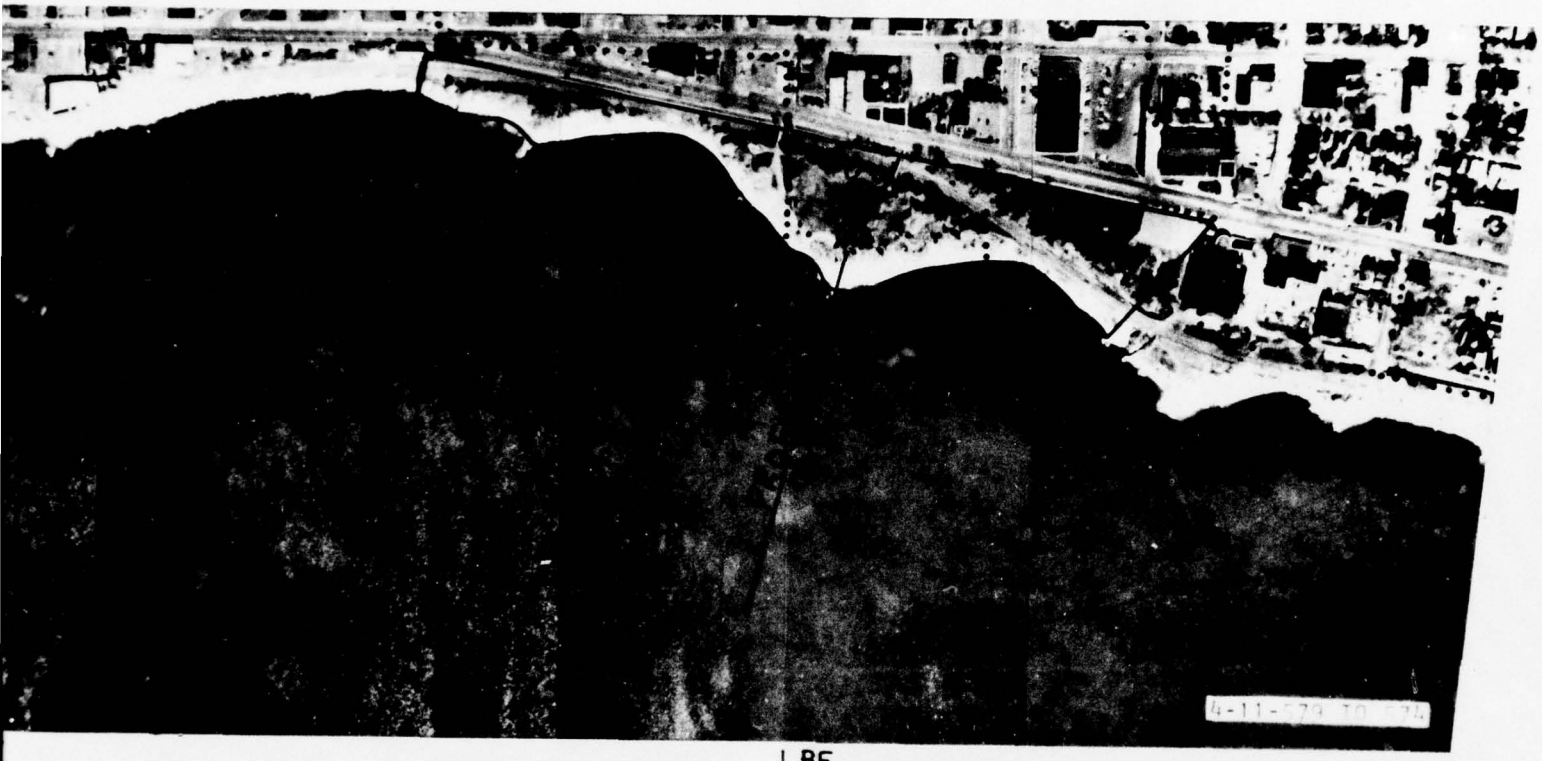
- [S] State
- (C) County
- (M) Municipal
- Private



LBE

ND OWNERSHIP

④ SHORELINE PROTECTION STRUCTURES - - - - - - -

⑤ FLOOD PLAIN . . . . . .

SCALE

0 feet 500

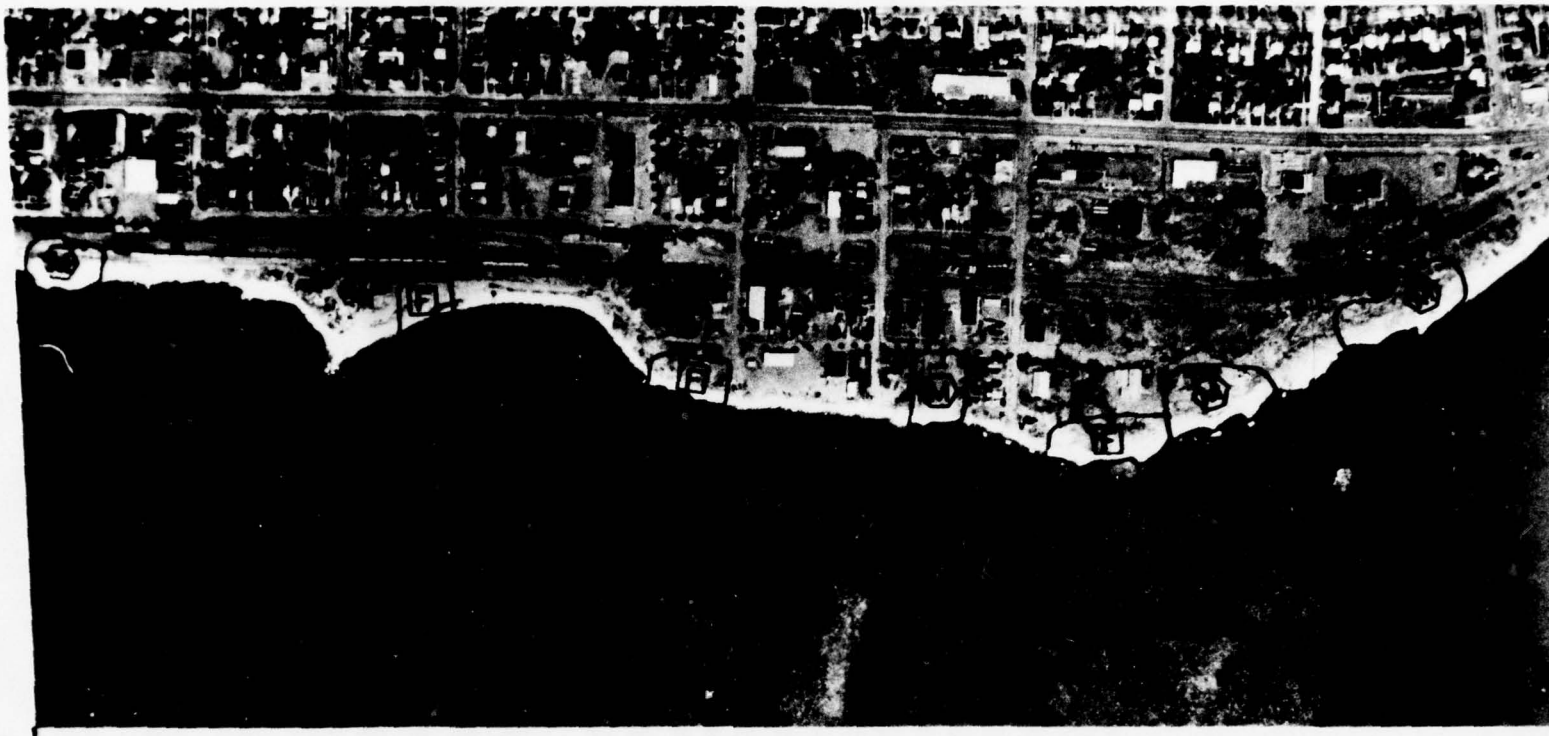
DEPARTMENT OF THE ARMY
NORTH CENTRAL DIVISION, CORPS OF ENGINEERS
CHICAGO, ILLINOIS

GREAT LAKES SHORELINE DAMAGE SURVEY

ST. LOUIS COUNTY, MINNESOTA
NOVEMBER, 1975

PLATE 10

2



LBN LBN

LEGEND

(1) SHOREFORMS

A	Artificial Fill Area
HBE	Erodible High Bluff-30 ft. or higher
HBN	Non-Erodible High Bluff-30 ft. or higher
LBE	Erodible Low Bluff-less than 30 ft.
LBN	Non-Erodible Low Bluff-less than 30 ft.
HD	High Sand Dune-30 ft. or higher
LD	Low Sand Dune-less than 30 ft.
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PN	Non-Erodible Low Plain
W	Wetlands

(2) SHORELAND USE

- [R] Residential
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- [T] Tax Exempt

(3) SHORELAND OWNERSI

- [F] Federal
- [S] State
- (C) County
- (M) Municipal
- Private

LBN

OWNERSHIP

(4) SHORELINE PROTECTION STRUCTURES - - - - - -

(5) FLOOD PLAIN . . . . . .

SCALE

0 feet 500

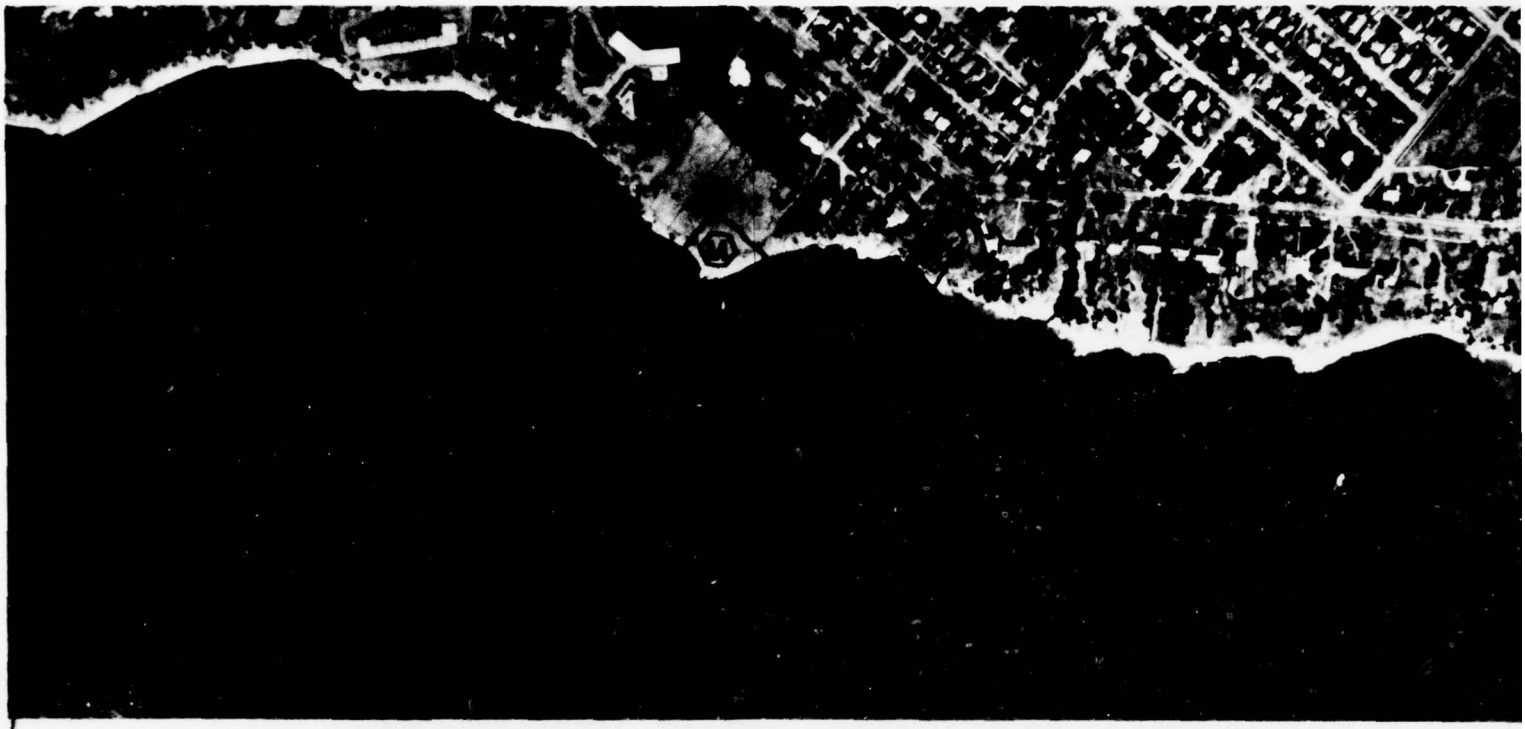
DEPARTMENT OF THE ARMY
NORTH CENTRAL DIVISION, CORPS OF ENGINEERS
CHICAGO, ILLINOIS

GREAT LAKES SHORELINE DAMAGE SURVEY

ST. LOUIS COUNTY, MINNESOTA
NOVEMBER, 1975

PLATE II

2



LBN LBN

LEGEND

(1) SHOREFORMS

A	Artificial Fill Area
HBE	Erodible High Bluff-30 ft. or higher
HBN	Non-Erodible High Bluff-30 ft. or higher
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(2) SHORELAND USE

- [R] Residential
- [C] Commercial
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- [M] Manufacturing
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- [N] Non-Developed
- [T] Tax Exempt

(3) SHORELAND OWNE

- [F] Federal
- [S] State
- (C) County
- ⟨M⟩ Municipal
- Private

AD-A031 262 ARROWHEAD REGIONAL DEVELOPMENT COMMISSION DULUTH MINN F/G 13/2
PILOT STUDY PROGRAM, GREAT LAKES SHORELAND DAMAGE STUDY. APPEND--ETC(U)
MAY 76 DACW23-75-C-0023
UNCLASSIFIED NL

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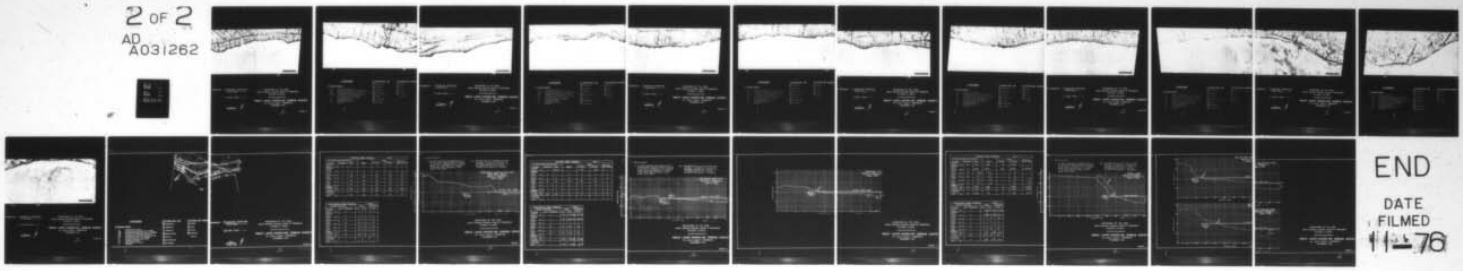

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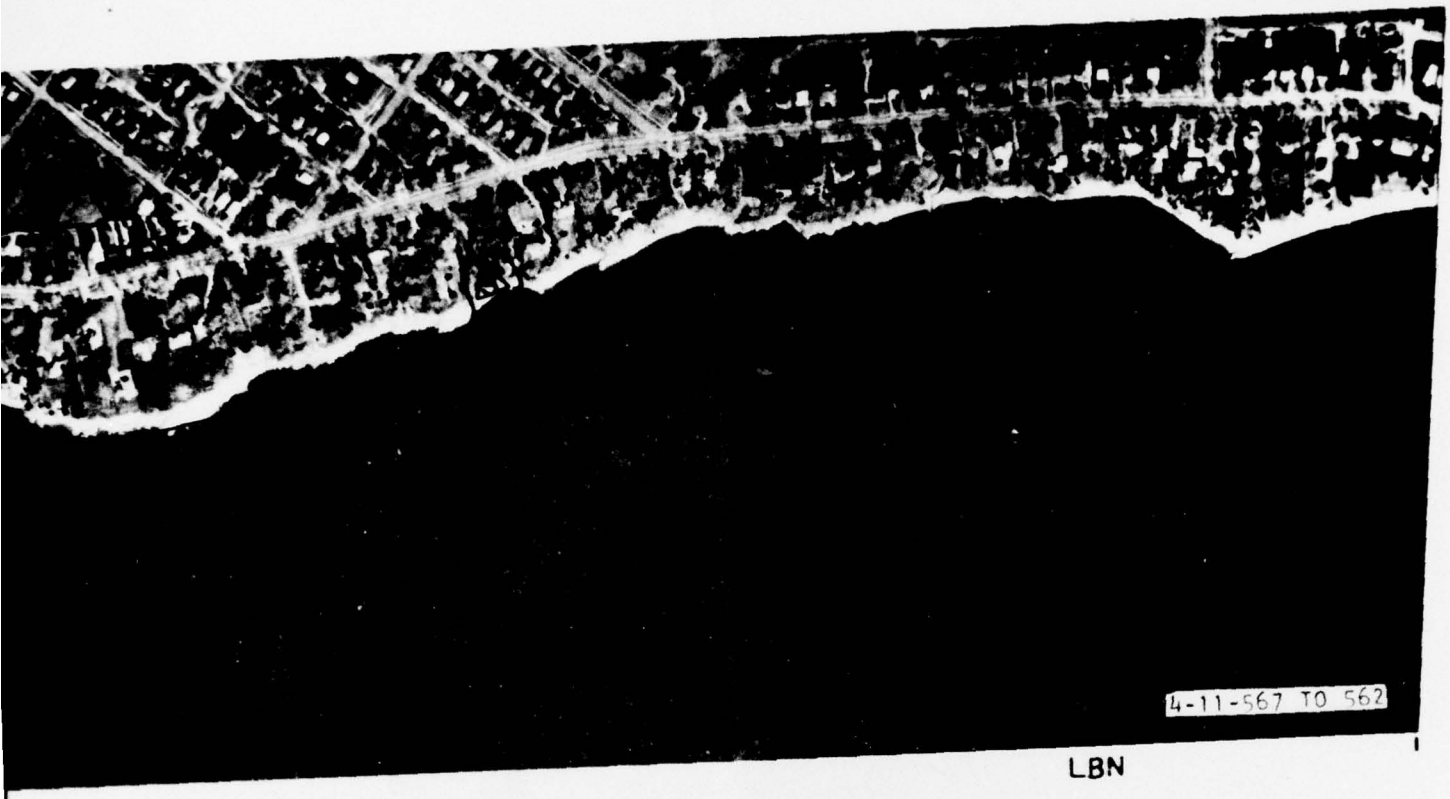

LBN

OWNERSHIP

④ SHORELINE PROTECTION STRUCTURES - - - - - -

⑤ FLOOD PLAIN . . . . . .

SCALE

0 feet 500

DEPARTMENT OF THE ARMY
NORTH CENTRAL DIVISION, CORPS OF ENGINEERS
CHICAGO, ILLINOIS

GREAT LAKES SHORELINE DAMAGE SURVEY

ST. LOUIS COUNTY, MINNESOTA
NOVEMBER, 1975

2

PLATE 12

LEGEND

(1) SHOREFORMS

A	Artificial Fill Area
HBE	Erodible High Bluff-30 ft. or higher
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W	Wetlands

(2) SHORELAND USE

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- [C] Commercial
- [I] Industrial
- [M] Manufacturing
- [U] Utility
- [N] Non-Developed
- [T] Tax Exempt

(3) SHORELAND OWNER

- [F] Federal
- [S] State
- (C) County
- ⟨M⟩ Municipal
- Private

LBE

D OWNERSHIP

④ SHORELINE PROTECTION STRUCTURES ------

⑤ FLOOD PLAIN ·····

SCALE

0 feet 500

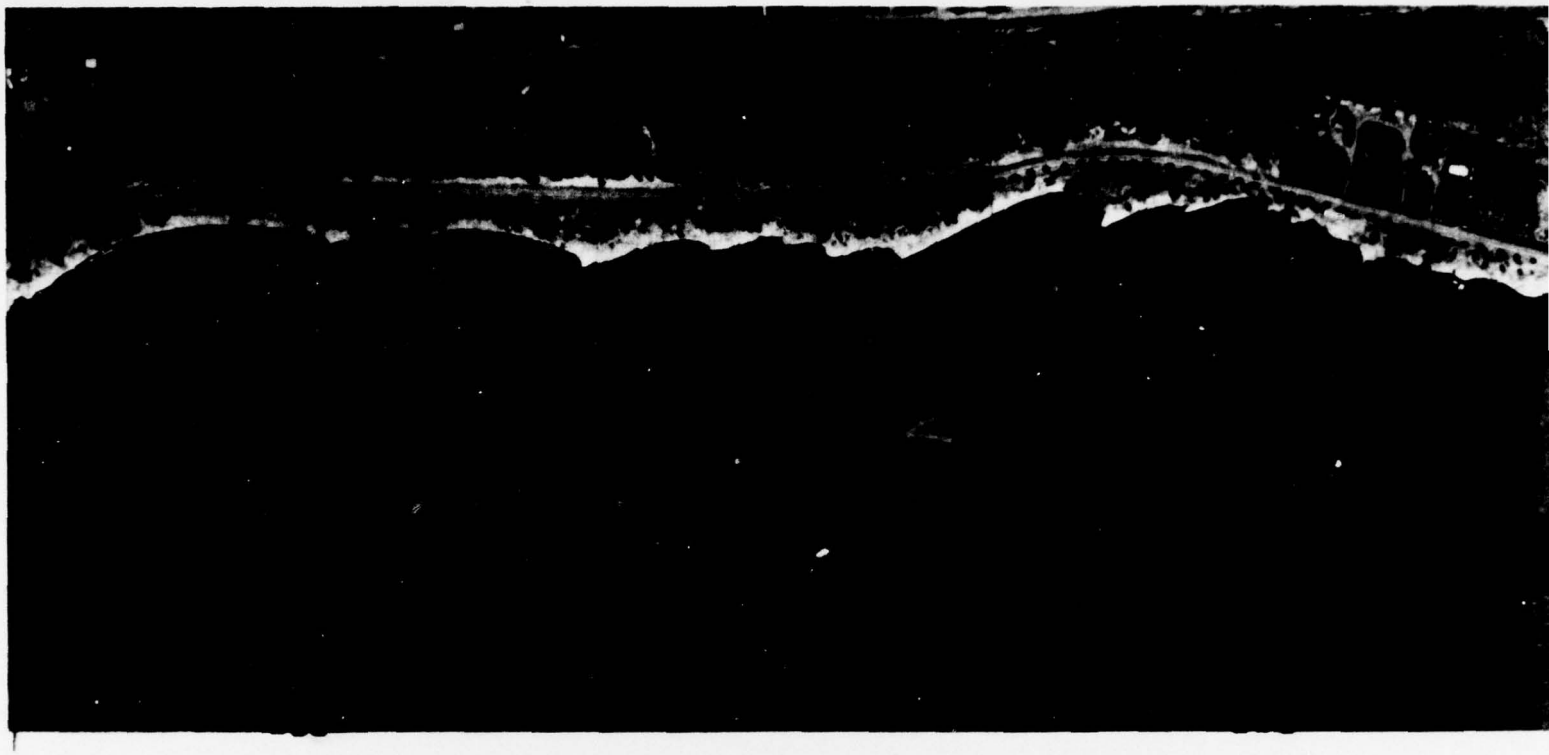
DEPARTMENT OF THE ARMY
NORTH CENTRAL DIVISION, CORPS OF ENGINEERS
CHICAGO, ILLINOIS

GREAT LAKES SHORELINE DAMAGE SURVEY

ST. LOUIS COUNTY, MINNESOTA
NOVEMBER, 1975

PLATE 13

2



LEGEND

(1) SHOREFORMS

A	Artificial Fill Area
HBE	Erodible High Bluff-30 ft. or higher
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(2) SHORELAND USE

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- [I] Industrial
- [M] Manufacturing
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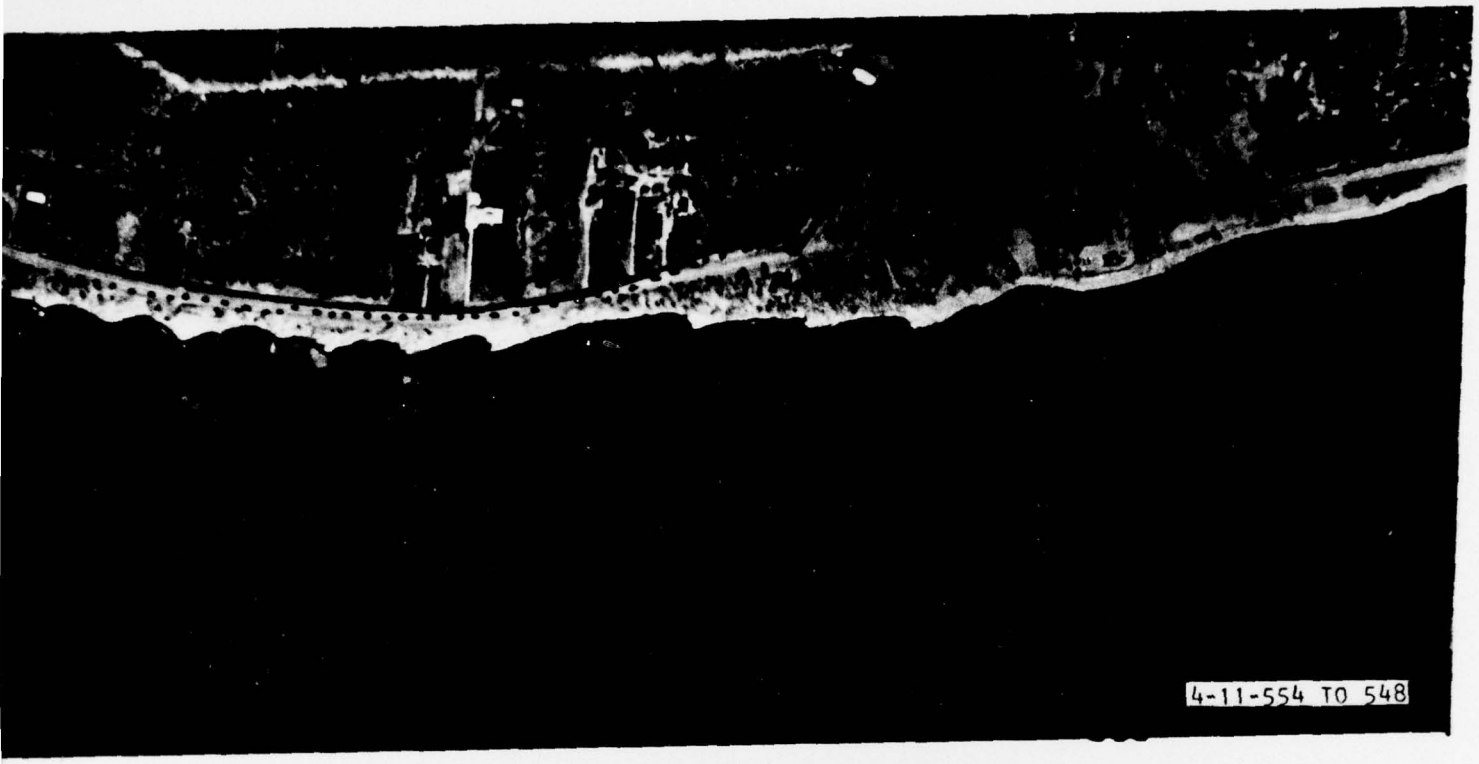
- [T] Tax Exempt

(3) SHORELAND OWNERS

- [F] Federal
- [S] State
- (C) County
- ⟨M⟩ Municipal
- Private



OWNERSHIP

④ SHORELINE PROTECTION STRUCTURES ------

⑤ FLOOD PLAIN ·····

SCALE

0 feet 500

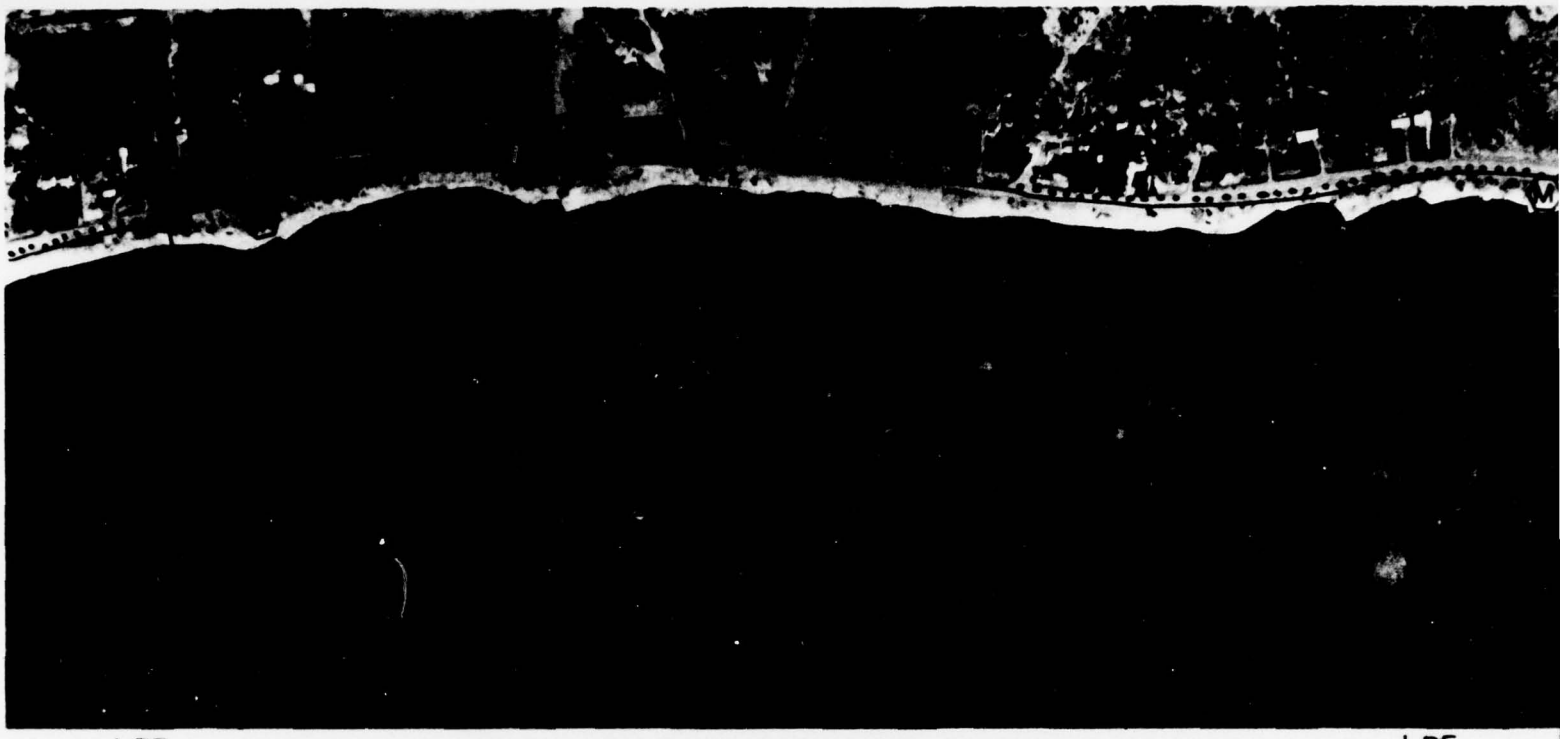
DEPARTMENT OF THE ARMY
NORTH CENTRAL DIVISION, CORPS OF ENGINEERS
CHICAGO, ILLINOIS

GREAT LAKES SHORELINE DAMAGE SURVEY

ST. LOUIS COUNTY, MINNESOTA
NOVEMBER, 1975

PLATE 14

2



LEGEND

(1) SHOREFORMS

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- ⟨M⟩ Municipal
- Private

OWNERSHIP

④ SHORELINE PROTECTION STRUCTURES ------

⑤ FLOOD PLAIN ·····

SCALE
0 feet 500

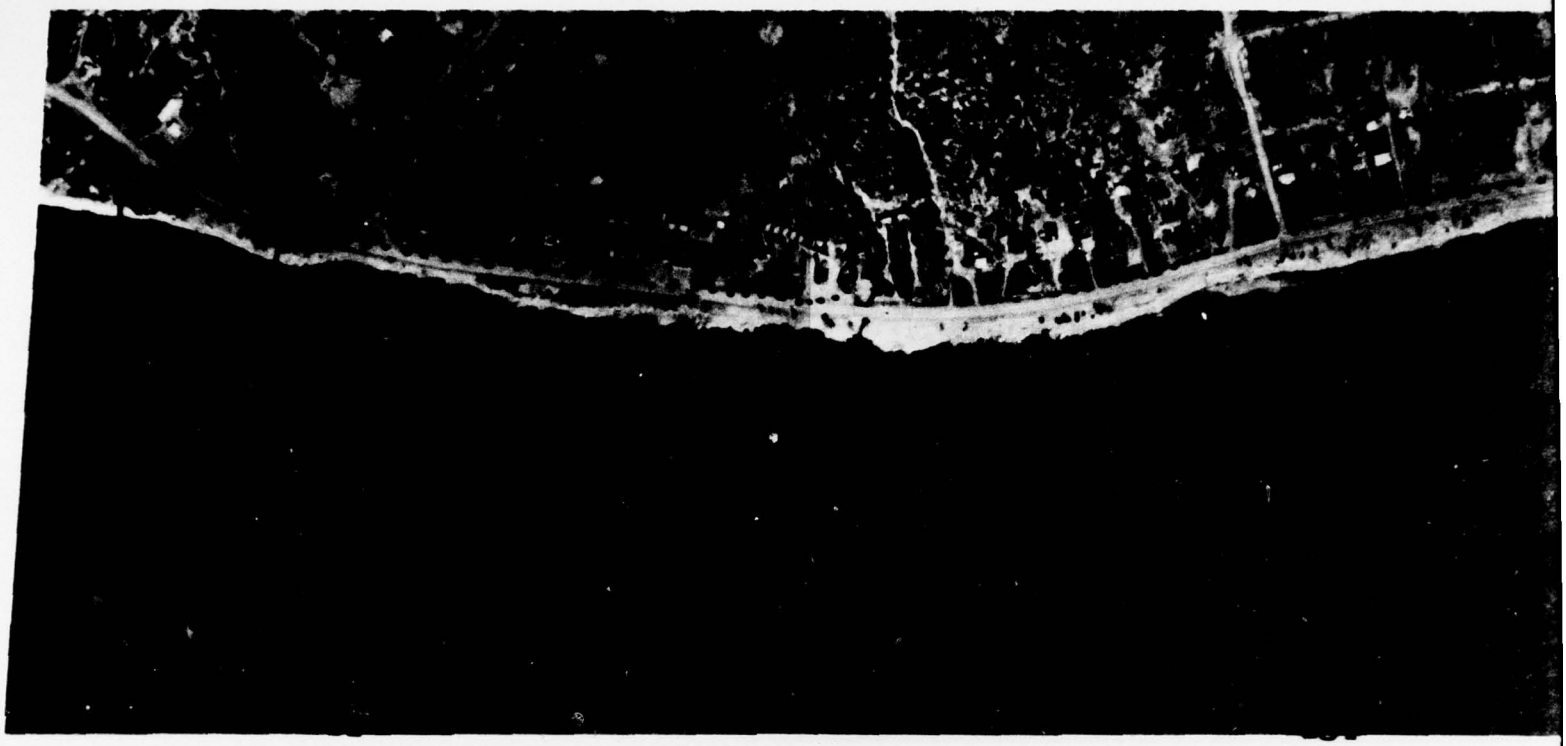
DEPARTMENT OF THE ARMY
NORTH CENTRAL DIVISION, CORPS OF ENGINEERS
CHICAGO, ILLINOIS

GREAT LAKES SHORELINE DAMAGE SURVEY

ST. LOUIS COUNTY, MINNESOTA
NOVEMBER, 1975

2

PLATE 15



LEGEND

(1) SHOREFORMS

A	Artificial Fill Area
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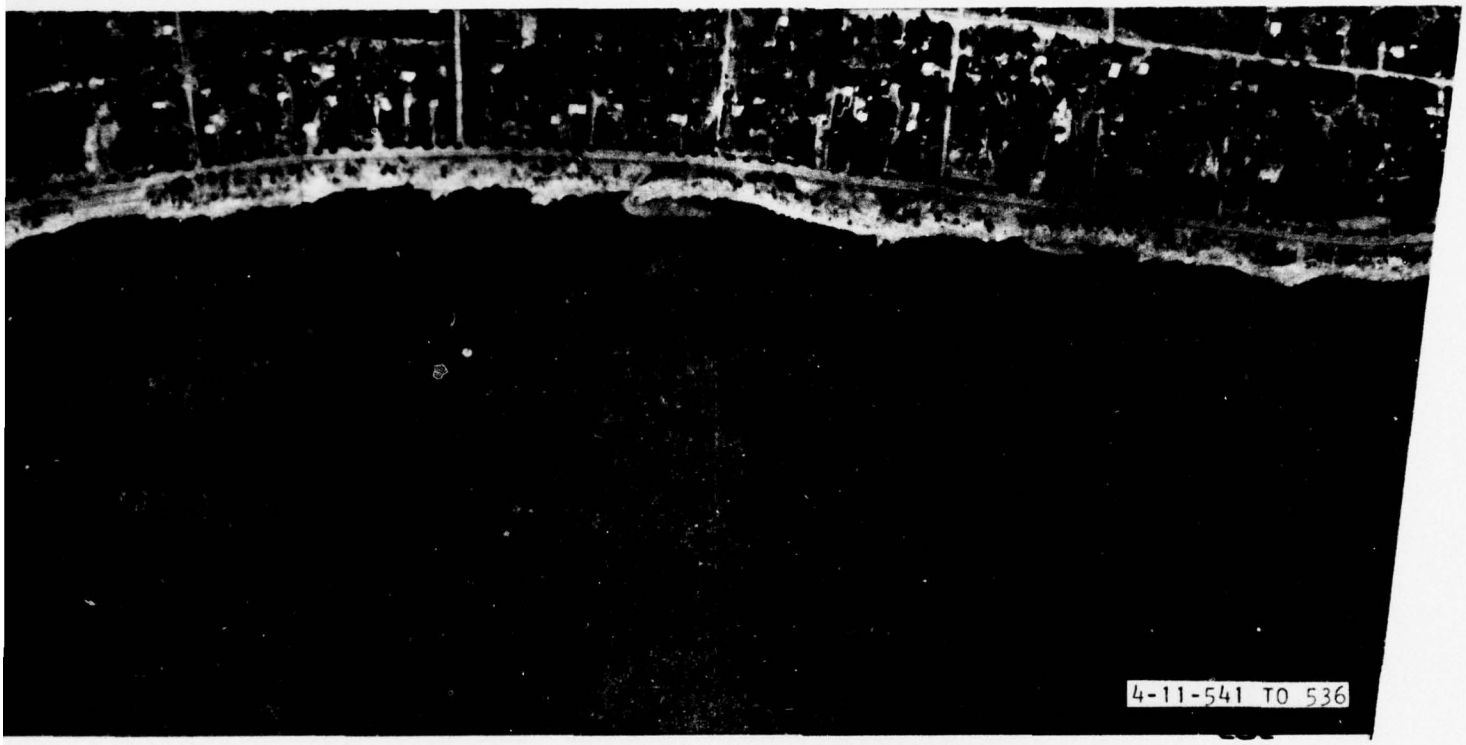
- Private



OWNERSHIP

(4) SHORELINE PROTECTION STRUCTURES ------

(5) FLOOD PLAIN ·····

SCALE

0 feet 500

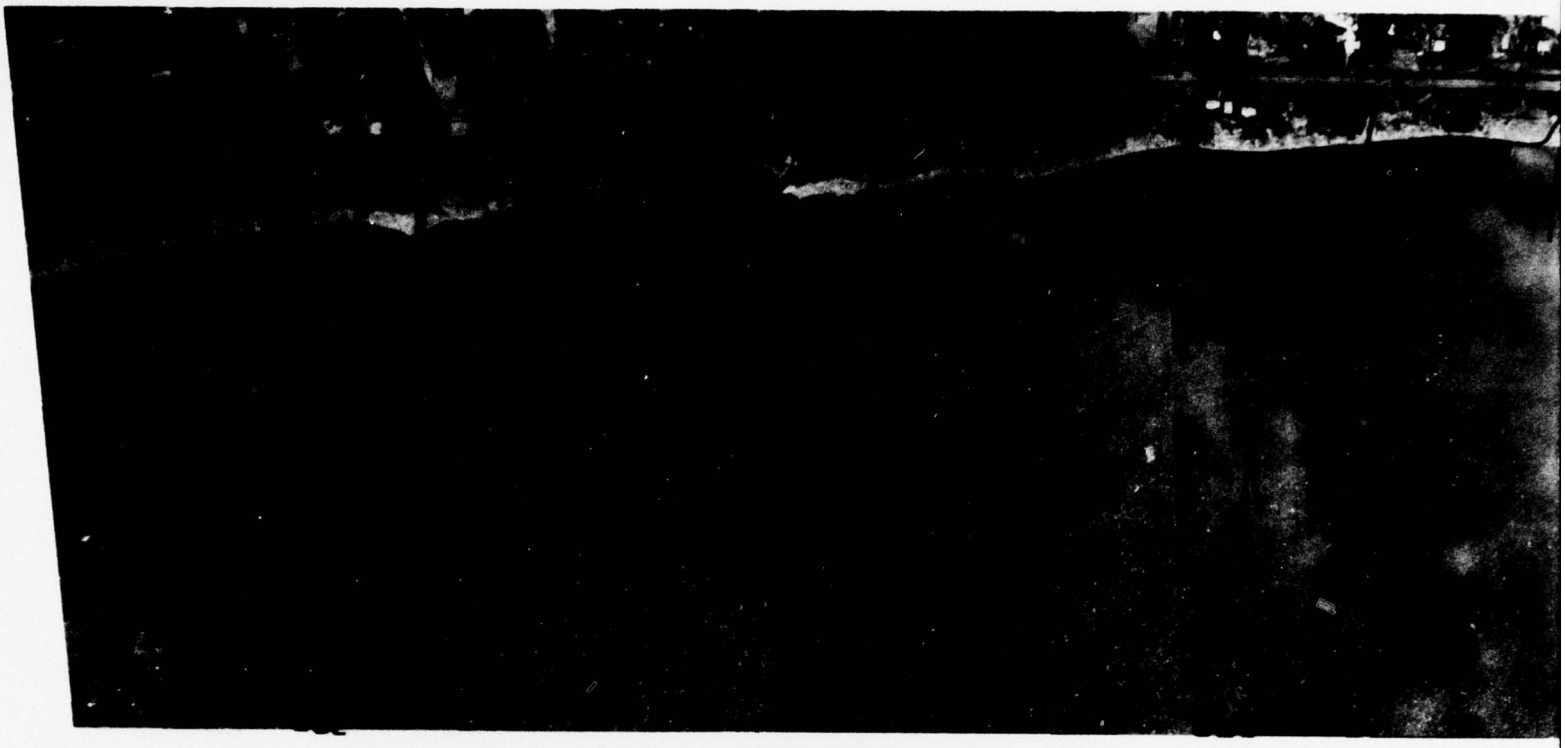
DEPARTMENT OF THE ARMY
NORTH CENTRAL DIVISION, CORPS OF ENGINEERS
CHICAGO, ILLINOIS

GREAT LAKES SHORELINE DAMAGE SURVEY

ST. LOUIS COUNTY, MINNESOTA
NOVEMBER, 1975

2

PLATE 16



LEGEND

(1) SHOREFORMS

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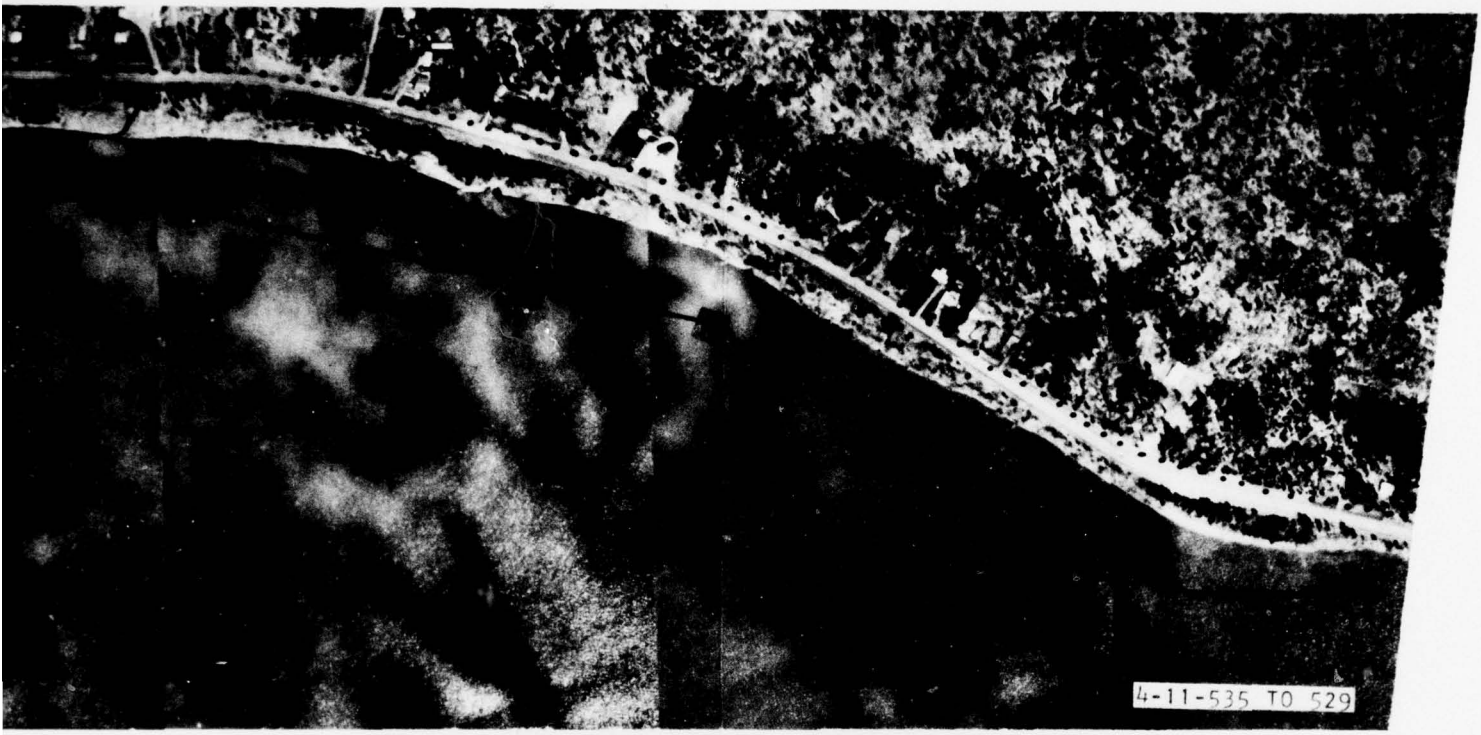

OWNERSHIP

④ SHORELINE PROTECTION STRUCTURES ------

⑤ FLOOD PLAIN ·····

SCALE
0 feet 500

DEPARTMENT OF THE ARMY
NORTH CENTRAL DIVISION, CORPS OF ENGINEERS
CHICAGO, ILLINOIS

GREAT LAKES SHORELINE DAMAGE SURVEY

ST. LOUIS COUNTY, MINNESOTA
NOVEMBER, 1975

2

PLATE 17

LBE

LB

LEGEND

(1) SHOREFORMS

A	Artificial Fill Area
HBE	Erodible High Bluff-30 ft. or higher
HBN	Non-Erodible High Bluff-30 ft. or higher
LBE	Erodible Low Bluff-less than 30 ft.
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- [S] State
- (C) County
- ⟨M⟩ Municipal
- Private

LBE HBE

OWNERSHIP

(4) SHORELINE PROTECTION STRUCTURES ------

(5) FLOOD PLAIN ·····

SCALE
0 feet 500

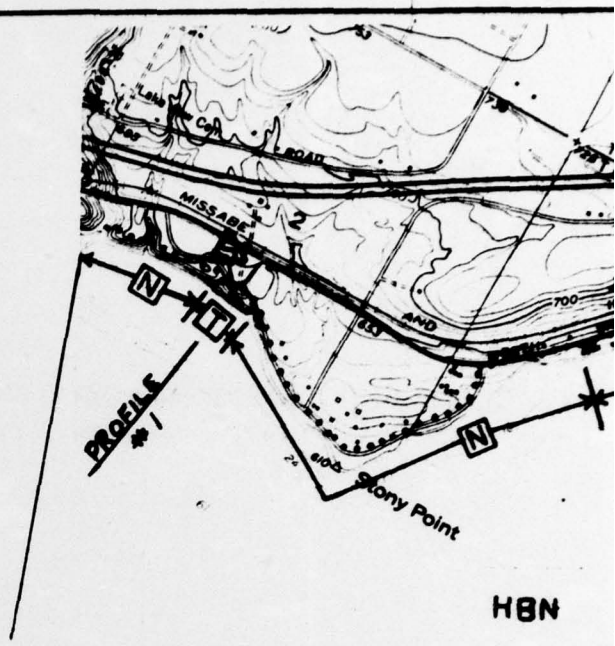
DEPARTMENT OF THE ARMY
NORTH CENTRAL DIVISION, CORPS OF ENGINEERS
CHICAGO, ILLINOIS

GREAT LAKES SHORELINE DAMAGE SURVEY

ST. LOUIS COUNTY, MINNESOTA
NOVEMBER, 1975

2

PLATE 18



HBN

LEGEND

(1) SHOREFORMS

A	Artificial Fill Area
HBE	Erodible High Bluff-30 ft. or higher
HBN	Non-Erodible High Bluff-30 ft. or higher
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- [T] Tax Exempt

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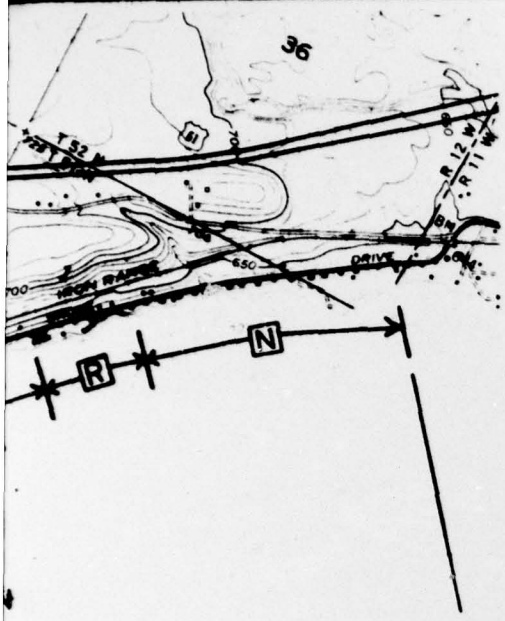

OWNERSHIP

④ SHORELINE PROTECTION STRUCTURES ------

⑤ FLOOD PLAIN ••••••

SCALE

0 feet 2000

DEPARTMENT OF THE ARMY
NORTH CENTRAL DIVISION, CORPS OF ENGINEERS
CHICAGO, ILLINOIS

GREAT LAKES SHORELINE DAMAGE SURVE

ST. LOUIS COUNTY, MINNESOTA
NOVEMBER, 1975

PLATE

2

RESIDENTIAL DAMAGE INFORMATION					Reach 1	
Self-Administered Questionnaire				Range		
Variable	Responses	Mean	Median	Minimum	Maximum	Question-naire Totals
Assessed Value ($)	D	D	D	D	D	D
Reported Market Value ($)	D	D	D	D	D	D
Bluff Height (Ft.)	0	N/A	N/A	N/A	N/A	N/A
Beach Depth (Ft.)	0	N/A	N/A	N/A	N/A	N/A
Bluff Lost (Ft.)	0	N/A	N/A	N/A	N/A	N/A
Beach Lost (Ft.)	0	N/A	N/A	N/A	N/A	N/A
DAMAGES Erosion ($)	0	N/A	N/A	N/A	N/A	N/A
Flooding ($)	0	N/A	N/A	N/A	N/A	N/A
Protective Structure Cost ($)	0	N/A	N/A	N/A	N/A	N/A

NON RESIDENTIAL DAMAGE INFORMATION				REACH 1
Personal Interviews		Range		Interview
Variable	No. of Responses	Min.	Max.	Totals
Assessed Value ($)	D	D	D	D
Reported Market Value ($)	D	D	D	D
Bluff Height (Ft.)	N/A	N/A	N/A	N/A
Beach Depth (Ft.)	N/A	N/A	N/A	N/A
Bluff Lost (Ft.)	N/A	N/A	N/A	N/A
Beach Lost (Ft.)	N/A	N/A	N/A	N/A
DAMAGES Erosion ($)	N/A	N/A	N/A	N/A
Flooding ($)	D	D	D	D
Protective Structure Cost ($)	D	D	D	D

ELEVATION IN FEET

640
620
600
580
0

1) Define D and N/A

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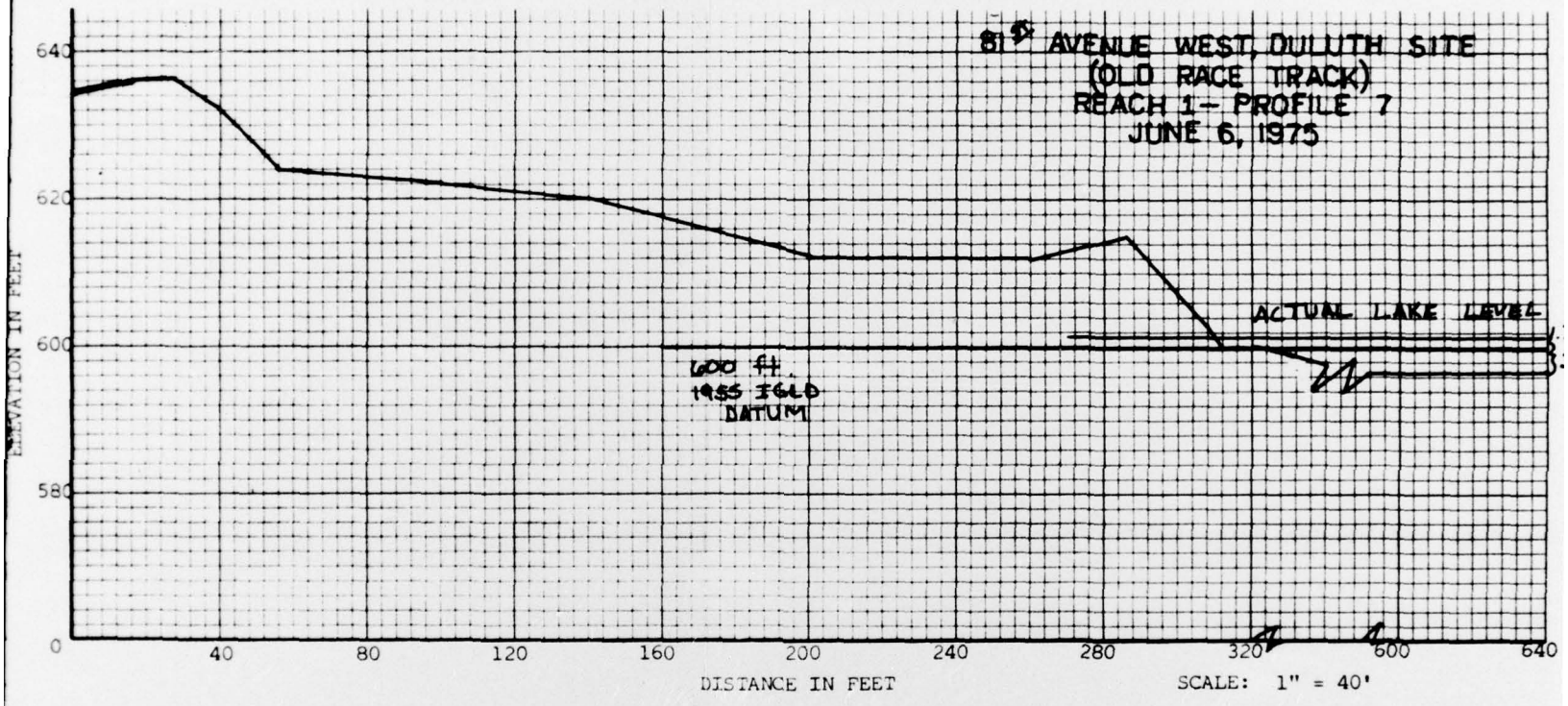


DEPARTMENT OF THE ARMY
NORTH CENTRAL DIVISION, CORPS OF ENGINEERS
CHICAGO, ILLINOIS

GREAT LAKES SHORELINE DAMAGE SURVE

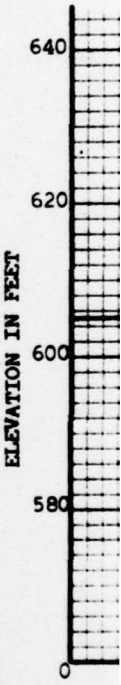
ST. LOUIS COUNTY, MINNESOTA
NOVEMBER, 1975

REACH I

RESIDENTIAL DAMAGE INFORMATION				Reach 2		
Self-Administered Questionnaire			Median	Range		Questionnaire Totals
Variable	Responses	Mean		Minimum	Maximum	
Assessed Value ($)	3	841.25		215	1,425	
Reported Market Value ($)	D	D	D	D	D	D
Bluff Height (Ft.)	D	D	D	D	D	D
Beach Depth (Ft.)	N/A	N/A	N/A	N/A	N/A	D
Bluff Lost (Ft.)	D	D	D	D	D	D
Beach Lost (Ft.)	D	D	D	D	D	D
DAMAGES Erosion ($)	D	D	D	D	D	D
Flooding ($)	N/A	N/A	D	D	D	D
Protective Structure Cost ($)	D	D	D	D	D	D

NON RESIDENTIAL DAMAGE INFORMATION				REACH 2
Personal Interviews		Range		Interview
Variable	No. of Responses	Min.	Max.	Totals
Assessed Value ($)	8	3,812	1,186,248	2,745,576
Reported Market Value ($)	8	7,400	4,032,730	7,682,330
Bluff Height (Ft.)	D	D	D	D
Beach Depth (Ft.)	N/A	N/A	N/A	N/A
Bluff Lost (Ft.)	D	D	D	D
Beach Lost (Ft.)	N/A	N/A	N/A	N/A
DAMAGES Erosion ($)	D	D	D	D
Flooding ($)	5	7,700	167,000	352,200
Protective Structure Cost ($)	3	1,750	15,000	26,750

1)



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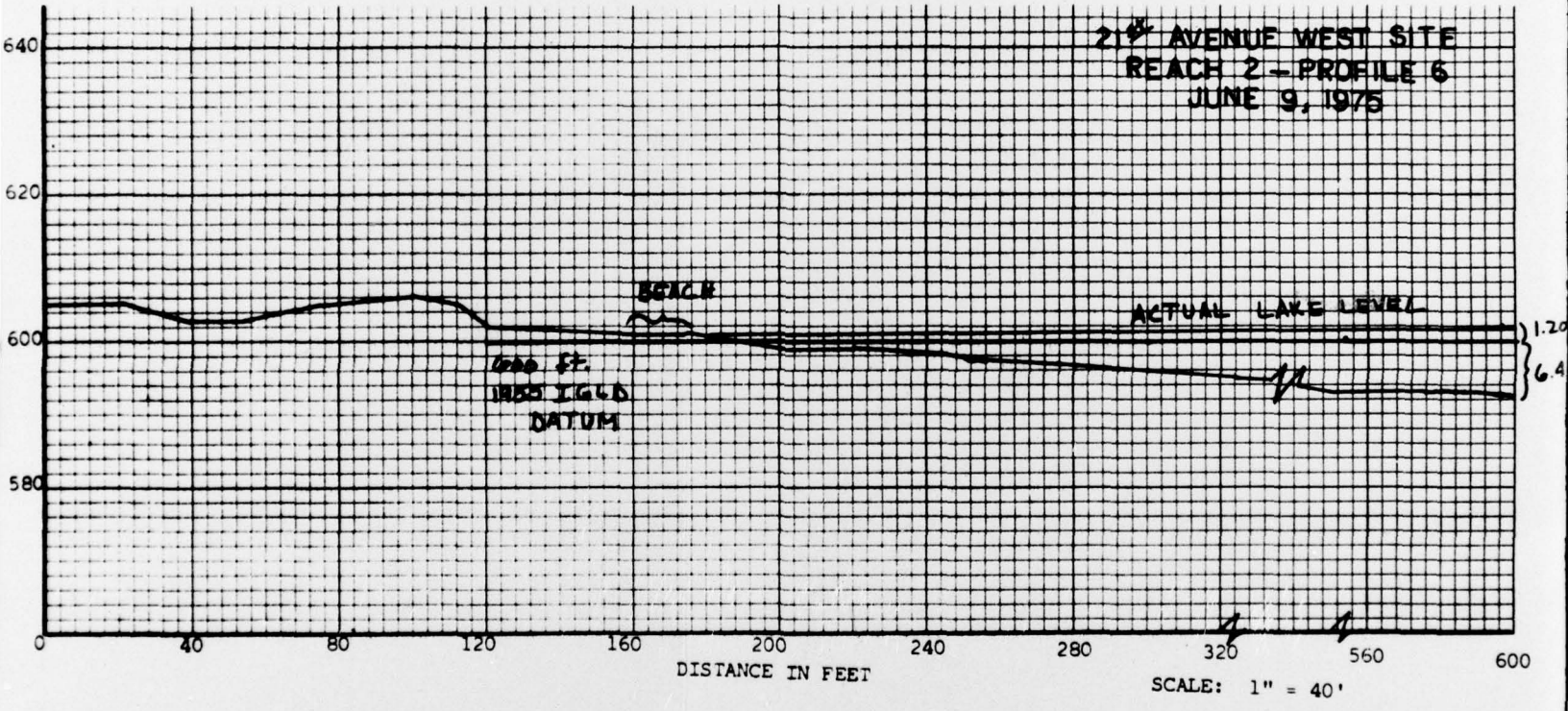

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CHICAGO, ILLINOIS

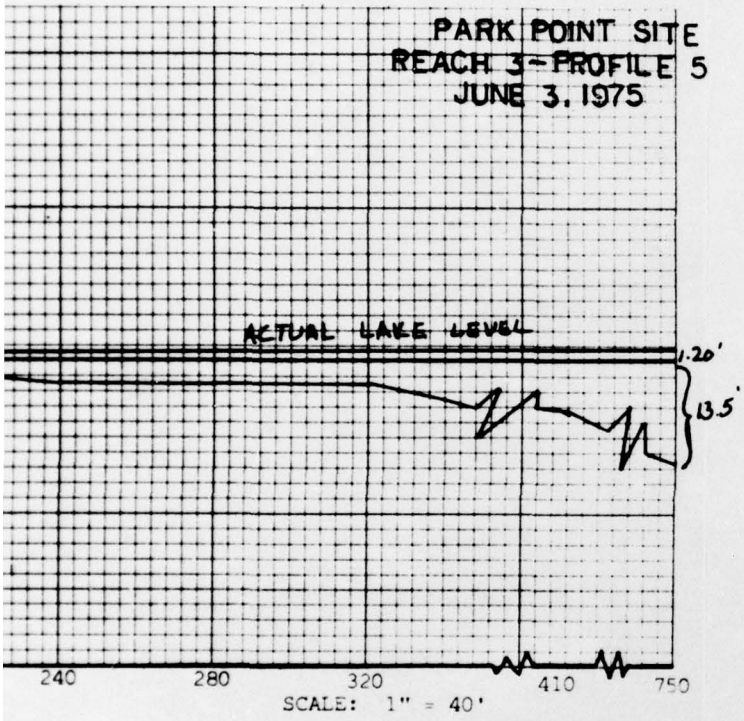
GREAT LAKES SHORELINE DAMAGE SURVEY

ST. LOUIS COUNTY, MINNESOTA
NOVEMBER, 1975

REACH 2

640
620
600
580
0
40
80
120
160
200
24
ELEVATION IN FEET
DISTANCE IN FEET
BEACH
DATUM

1



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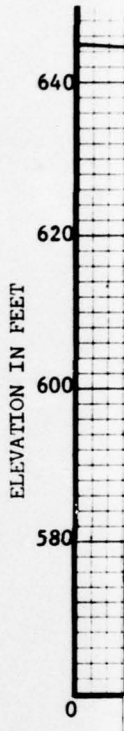
GREAT LAKES SHORELINE DAMAGE SURVEY

ST. LOUIS COUNTY, MINNESOTA
NOVEMBER, 1975

REACH 3

RESIDENTIAL DAMAGE INFORMATION				Reach 4		
Self-Administered Questionnaire				Range		
Variable	Responses	Mean	Median	Minimum	Maximum	Questionnaire Totals
Assessed Value ($)	157	8,365	6,920	40	45,320	
Reported Market Value ($)	74	45,258	40,614	1,000	150,000	3,349,100
Bluff Height (Ft.)	106	21.58	19.21	4	75	
Beach Depth (Ft.)	82	14.6	14.0	1	45	
Bluff Lost (Ft.)	71	10.0	6.42	1	130	712
Beach Lost (Ft.)	80	12.4	9.20	1	200	994
DAMAGES						
Erosion ($)	76	2,805	1,883	50	30,000	213,210
Flooding ($)	52	1,777	1,216	30	10,000	92,387
Protective Structure Cost ($)	26	3,092	390	75	9,999	81,514

NON RESIDENTIAL DAMAGE INFORMATION				REACH 4
Personal Interviews		Range		Interview
Variable	No. of Responses	Min.	Max.	Totals
Assessed Value ($)	9	430	4,797,510	5,239,599
Reported Market Value ($)	9	1,000	11,157,001	12,262,131
Bluff Height (Ft.)	8	17'	65'	294'
Beach Depth (Ft.)	D	D	D	D
Bluff Lost (Ft.)	D	D	D	D
Beach Lost (Ft.)	6	10'	27'	90'
DAMAGES				
Erosion ($)	4	300	6,500	8,700
Flooding ($)	N/A	N/A	N/A	N/A
Protective Structure Cost ($)	3	1,000	5,250	8,250



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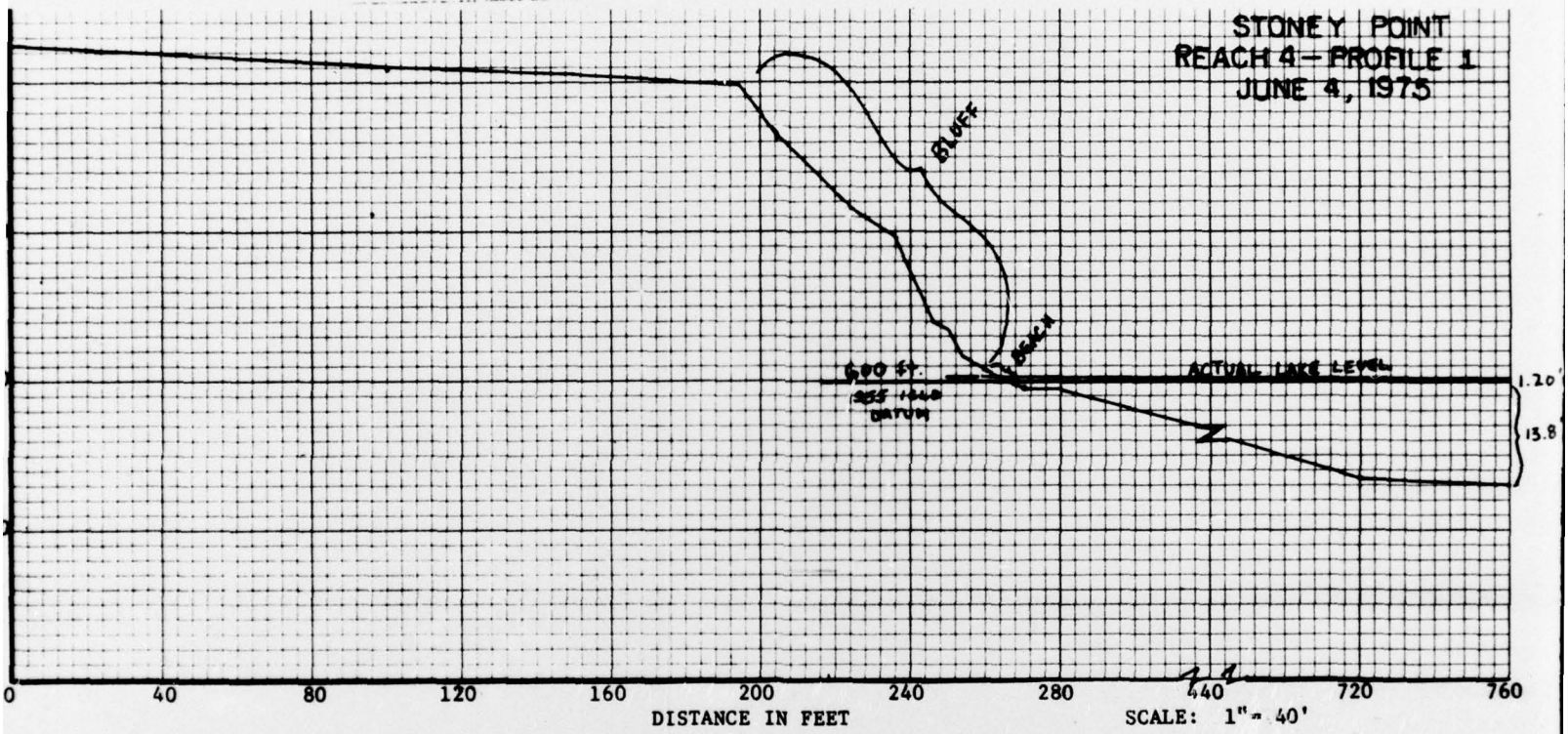

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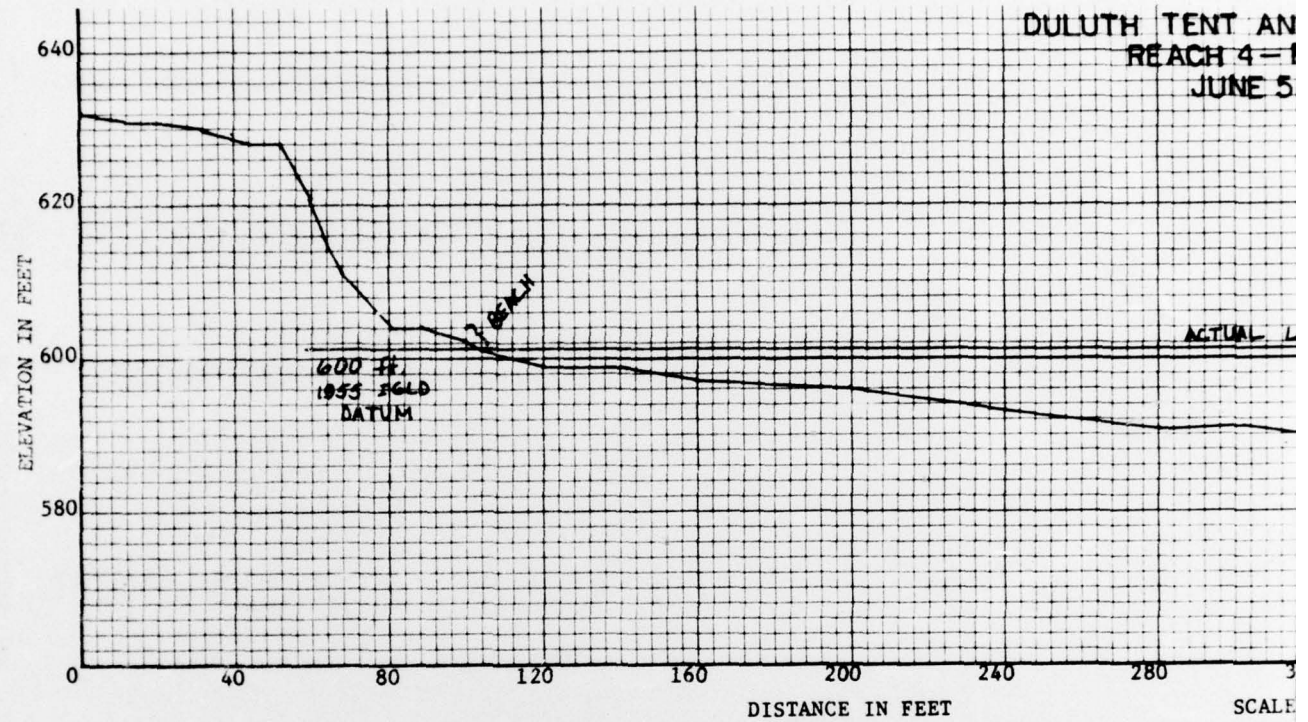
GREAT LAKES SHORELINE DAMAGE SURVEY

ST. LOUIS COUNTY, MINNESOTA
NOVEMBER, 1975

REACH 4


DULUTH TENT AN
REACH 4 – 1
JUNE 5
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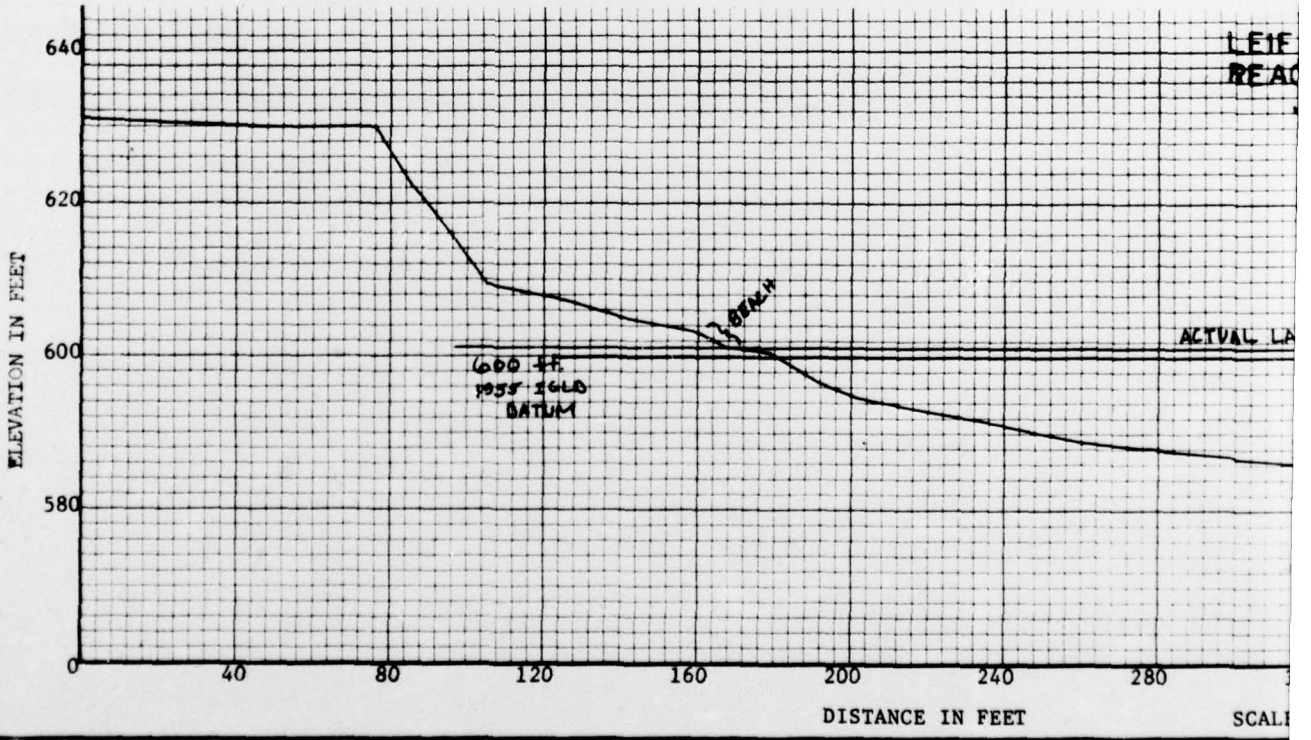
ELEVATION IN FEET
600 FT.
1955 IGLD
DATUM
ACTUAL L
DISTANCE IN FEET
SCALE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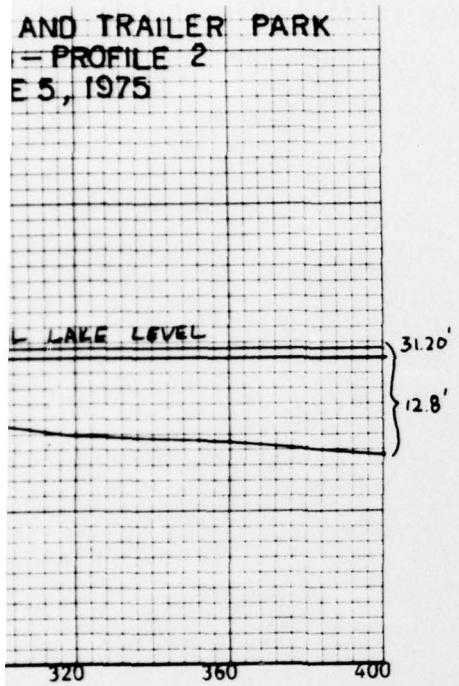
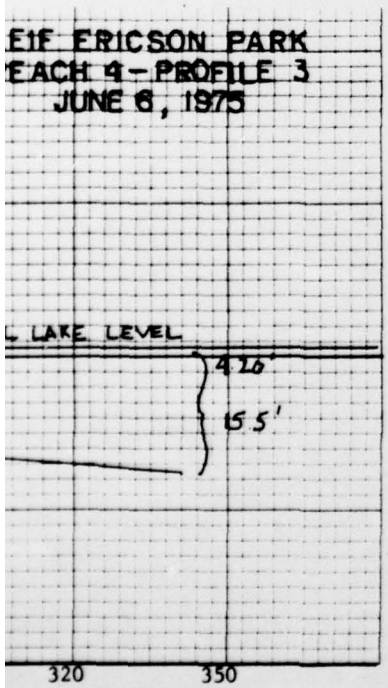
ELEVATION IN FEET
600 FT.
1955 IGLD
DATUM
ACTUAL LA
DISTANCE IN FEET
SCALE



SCALE: 1" = 40'



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REACH 4

2